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1960
ANNUAL PROGRESS REPORT
RANGE REVEGETATION INVESTIGATIONS

FORAGE & RANGE BRANCH
CROPS RESEARCH DIVISION
UNITED STATES DEPARTMENT OF AGRICULTURE

in cooperation with

INTERMOUNTAIN FOREST
AND RANGE EXPERIMENT STATION
and
UTAH AGRICULTURAL EXPERIMENT STATION

by
A. T. BLEAK, RANGE CONSERVATIONIST
EPHRAIM, UTAH

Copy Number 3

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Intermountain Forest and Range Experiment Station

Soil Conservation Service

Utah State University

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CRc6: PASTURE AND RANGE INVESTIGATIONS UNDER ARID, SEMI-ARID, AND SUB-HUMID CONDITIONS

I. Introduction

The following report covers the artificial revegetation investigations conducted in central Utah during the period April 1, 1960 to March 31, 1961. This is the fifth annual progress report that has been submitted since the work in central Utah was reactivated in the late summer of 1956.

Research has been primarily in three fields:

1. Evaluation of grasses and legumes alone and in combinations for adaptation to range conditions -- Suitable species are needed to increase forage production, to maintain soil stability, and prevent destructive floods. Species should be used which are adapted to the environment. Species may be well adapted to a particular climate or soil, but still fail because of some other environmental factors. This had led to an effort to distinguish between those inherent climatic and edaphic factors which must be met by species selection as opposed to factors such as grazing use, insects, rodents, and disease.

2. Establishment practices for revegetation of range areas in the West -- Suitable establishment practices are necessary for consistently successful and effective revegetation of depleted ranges on which the present plant cover is not adequate for soil protection or is of low forage value. The reseeding program is expanding into extremes of climate and soils where little is known about reseeding. This magnifies the importance of "know-how" in restoring the vegetation cover. Low precipitation, dry summer, sandy soil, acid soil, steep slopes and rough terrain are some of the factors which require special consideration.

3. Physiological responses of grasses and legumes to environmental factors -- Physiological studies on response of plants to environment factors provide information needed for selection of suitable species and methods and for successful establishment and management. Reasons for specific responses by seeds and plants to certain factors in the environment must be understood to predict behavior from site to site. This understanding will not only assist in selection of species, sites, and management, but should also show where modification of certain environment factors may be desirable.

A. Foreign Visitors and Technical Assistance

Approximately 10 hours were spent with Dr. Jorge Morello from Argentina and Dr. N. Tadmor from Israel. In addition, 40 hours were spent giving technical assistance and reviewing research findings with extension workers, action agencies, and private groups.

B. Vehicles at Ephraim, Utah

1. 1954 truck pickup, 1/2-Ton, Ford V-2593-ARS, Lic. A-52355. Mileage on March 1, 1961 -- 54,139 - good condition.
2. 1955 truck pickup, 1/2-Ton, Willys Jeep, V2593-ARS, Lic. A-57211. Mileage on March 1, 1961 -- 36,422 -- poor condition.

II. Northern Desert Shrub Type

II-A. Revegetation

The northern desert range lands of this region cannot be considered a single homogeneous type, similar to the big sagebrush or pinyon-juniper types. This type can be conveniently broken down into several distinct communities or associations. These are permanent communities, to some extent determined by soil conditions within the limits set by climate. The most important or largest communities are listed below in the order in which they frequently occur in going from the big sagebrush type toward the heavier, moister soils surrounding a lake or marsh on the valley floor.

1. Black sagebrush (Artemisia nova)
2. Galleta grass (Hilaria jamesi)
3. Little rabbitbrush (Chrysothamnus stenophyllus)
4. Winterfat (Eurotia lanata)
5. Shadscale (Atriplex confertifolia)
6. Greasewood (Sarcobatus vermiculatus)
7. Saltgrass (Distichlis stricta)
8. Pickleweed (Allenrolfea occidentalis)

In the black sagebrush, galleta, winterfat, and shadscale associations, physical drought is usually the principal limiting factor. Plant growth is restricted by available moisture in the soil as a result of precipitation and soil characteristics. Drought tolerance is generally more important than tolerance to high concentrations of soil salts. In the pickleweed, saltgrass, and greasewood associations, physiological drought may be more of a problem than soil moisture.

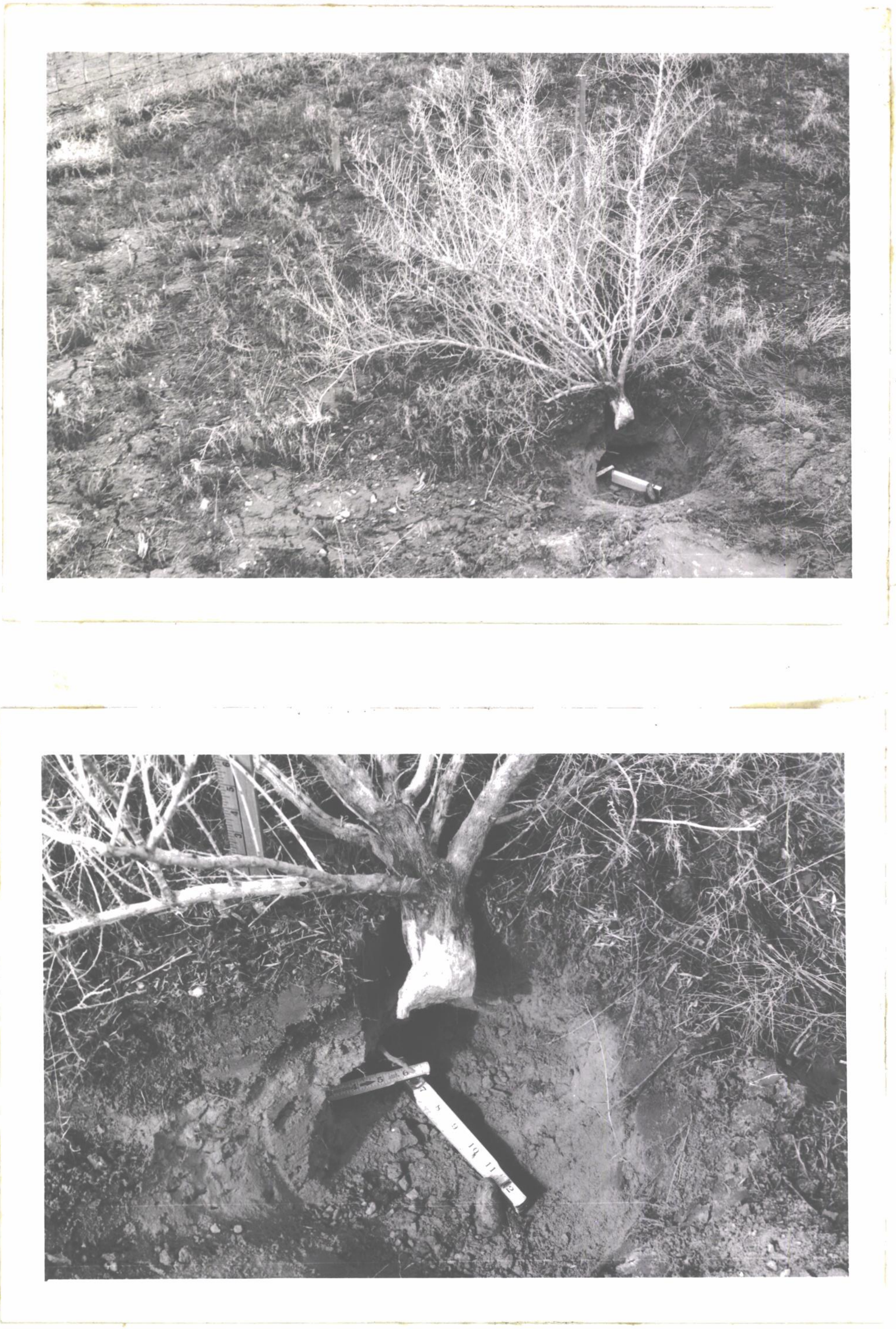
In general it can be said that the climate of this zone is distinctly drier than the sagebrush zone. The mean annual precipitation for six desert shrub stations in western Utah averaged 7.95 inches, while that for four sagebrush stations averaged 14.84 inches or again almost twice as much as in the desert shrub type. Dr. D. W. Billings reported mean annual precipitation at all stations in western Nevada and eastern California in the northern desert shrub type, ranged from 3.08 inches to 5.68 inches, with an average of 4.51 inches for the zone. This is about one-half the average mean annual precipitation of 8.79 inches for 6 stations in the sagebrush zone in northern and western Nevada.

Mean January temperatures in the northern desert shrub type appear to be higher than in the sagebrush zone. The summer temperatures of the northern desert shrub type in western Nevada are distinctly higher, about 5°F., than those in the sagebrush zone. The higher summer temperatures in the desert shrub zone are undoubtedly reflected in higher evaporation, resulting in greater aridity.

Due to climatic conditions, returns from the land are low in the desert types, as compared with other range types. Where the native perennial plants have been destroyed, annual grasses and forbs have frequently invaded. These annuals produce abundant herbage when climatic conditions are especially favorable, but during drought years plant cover may not be adequate to protect the soil. On some areas, the native perennial vegetation has been replaced by plants poisonous to livestock, such as halogeton. From the evidence we have to date, vast areas can and should be rehabilitated through management. Artificial revegetation is needed and justified on critical areas that need rapid revegetation, and on more productive lands where the returns will offset the cost of operation.

There are many factors contributing to the low herbage production and depleted conditions frequently found in the northern desert shrub type in addition to overgrazing and poor management of livestock. Low precipitation coupled with high evaporation are contributing factors which prevail throughout this zone. High salt content or loose, sandy, gravelly soils with a low water holding capacity are very common. It is evident that insects and rodents are a substantial factor for the low herbage production and poor results obtained from management practices or revegetation projects. Grasshoppers and cricket populations ravage the areas in some years. Ants harvest seeds and plants but in addition may occupy large areas. Rabbits and kangaroo rats are largely responsible for poor results obtained with seeded species, particularly with the cool season species which produce green growth in the early spring and in the fall when most other vegetation is dormant. As shown in figures 1 and 2 even pocket gophers damage native and seeded stands in this type.

As stated above, average precipitation on the northern desert shrub type ranges from only 3 to more than 8 inches per year. The precipitation pattern over most of this type has a high winter maximum, with some snow, and a summer minimum. Accumulated winter and early spring moisture is usually adequate for germination of the grass seeds commonly planted in this type. Most of the introduced grasses, forbs, and shrubs adapted to this type will germinate at relatively low temperatures. Germination from late fall plantings of crested wheatgrass seed and other seeded species has been observed and recorded from early December through



Figures 1 and 2.--This fourwing saltbush plant was killed when a gopher severed the roots. Apparently the missing section of root was used as food since all roots between the main plant stem and the protruding root stub near end of the rule had been removed from the soil (60-31 and 60-33).

May, depending on soil moisture, soil temperature or both. However, the seedlings perish unless spring and summer moisture conditions are favorable for seedling establishment. Since the seedlings frequently germinate during the winter and early spring, mortality due to the frost and freezing has been high.

Infrequent severe droughts may restrict seed germination. For example, during a severe drought in western Nevada from July 1954 to September 1955, only 1.47 inches of precipitation fell during this 13 month period. Seeds of planted grasses and shrubs, as well as native annuals and perennials, laid in the soil during the winter, spring, and summer without germinating. Seeds of four planted grasses (*Agropyron cristatum*, *A. desertorum*, *A. intermedium*, and *Elymus junceus*) were removed from this area in August 1955 after more than 8 months in the soil. These seeds were not visibly damaged and average percent germination in the laboratory was 80.9 percent while average germination of these same seed lots from stock supplies was 89.2 percent. Field germination from planted seeds of many of the grasses, all forbs, and two shrubs as well as many "native" annuals took place in late September 1955, soon after 1.42 inches of rain fell on this area. Some germination was noted for *Agropyron cristatum*, *A. desertorum*, *A. intermedium*, *A. sibiricum*, *A. trichophorum*, *Bromus breviaristatus*, *Elymus junceus*, *Sitanion hystrix*, *Kochia indica*, *K. scoparia*, *Erodium cicutarium*, and *Atriplex canescens*. Seeds that did not germinate were *Agropyron inerme*, *Elymus triticoides*, *Oryzopsis hymenoides*, *Stipa viridula* and most of the shrub species native to this type (*Artemisia spinescens*, *Atriplex confertifolia*, *A. gardneri*, *Eurotia lanata*, *Grayia spinosa*, and *Sarcobatus baileyi*).

Revegetation studies in the northern desert shrub types of Utah and Nevada have shown that good seedling stands can usually be obtained from late fall planting with intermediate wheatgrass, tall wheatgrass, crested wheatgrass, Russian wildrye, and many other species. Most of these seedlings perished during the first summer. Crested wheatgrass and Russian wildrye appear to be the best adapted of the introduced grasses, but even established stands of these grasses have usually perished during drought years.

Various methods of planting have been tried. Methods which conserved moisture or provided for collection of additional moisture around the seed and plants have been most successful. This has usually been done by pitting or by making furrows which collect and hold supplemental water. Good stands have been obtained on desert lands at several locations in Utah and Nevada.

One of the most promising plantings was made by Mr. Victor Murray at Cisco, Utah in the spring of 1938. This planting was on clay soils derived from mancos shale and supporting shadscale type of vegetation. Eighteen acres of crested wheatgrass were planted, with a Planet Jr., in furrows that had previously been made with an alfalfa marker. In 1952, most of the plants still appeared thrifty and there was a moderate number of young plants and seedlings. The herbage production was reduced in 1953. By 1955, these plants were mostly dead, due to light use by horses and the drought in 1954. On July 10, 1955 only rows of dead grass, which had been heaved out during the winter of 1954 and early spring of 1955 could be seen. Remnants of these heaved plants could still be seen in the summer of 1960 (figures 3 and 4).

Figures 3 and 4.--Dead crested wheatgrass plants can still be seen along the old drill rows that were planted in the spring of 1938. This stand persisted until 1954 (60-132 and 60-134).

Four acres in Wah Wah Valley, west of Milford, Utah, were planted to mixtures of species in the fall of 1939 and replanted on November 25, 1940 after the 1939 planting failed. A mixture of *Agropyron cristatum*, *A. spicatum*, *A. smithi*, *Arrhenatherum elatius*, *Elymus simplex*, and *Poa bulbosa* were sown on a third of this area. The shrubs, *Atriplex canescens*, *A. nuttalli*, and *Eurotia lanata* were sown on a third of this area and a mixture of grasses and shrubs were sown on a third of the seeded area. The area planted was vegetated with a fair stand of *Eurotia lanata* and small patches of *Hilaria jamesii*, which were not disturbed prior to planting. No shrub seedlings from the 1939 or 1940 plantings were found. Crested wheatgrass grew and has invaded the adjoining plots. Many of the crested wheatgrass plants in the original drill rows are now dead but good seedling stands have been produced by natural revegetation when conditions were favorable and fair stands have been maintained. Forage yields are similar where the crested wheatgrass grows in mixture with native winterfat and where the winterfat grows in nearly pure stands. Where the crested wheatgrass and winterfat grow together, both show the effects of competition.

Four plantings involving 82 species and strains were made within the Colorado River Drainage in the fall of 1950. Despite a dry spring in 1951, seedling stands of one lot of squirreltail, Amur wheatgrass, intermediate wheatgrass, pubescent wheatgrass, crested wheatgrass, and Russian wildrye produced fair to good stands on all sites. In the spring

During drought years even crested wheatgrass and Russian wildrye, which have shown the most promise of the introduced species in this type, as well as native Indian ricegrass and Sitanion have perished. In the late fall of 1946 a planting containing 11 grasses was made in the upper shadscale type in Paradise Valley, Nevada. Stands of all species, except crested wheatgrass and Russian wildrye, gradually declined and completely died out in the 1954 drought. The crested wheatgrass and Russian wildrye maintained good stands until the 1954 drought, when 90 percent of the plants were dead and the 10 percent remaining had only 1 or 2 culms within the original plant which were living.

Near Fernley, Nevada, during the 1954-1955 drought, 96 percent of a stand of native Oryzopsis hymenoides plants with an original stand of .7 plant per square foot perished. The surviving plants had only 1 or 2 living culms within the original plant. However, by midsummer in 1956, 0.49 seedling Indian ricegrass plants per square foot were found on this area from seed that had laid over in the soil. Native shrubs such as Atriplex canescens, A. gardneri, A. confertifolia, Eurotia lanata, and Artemisia spinescens have withstood the frequent droughts much better than most native and introduced grasses. Good stands of these shrubs have been very difficult to obtain for several reasons. Probably most important is the low viability and dormancy of shrub seeds, but rodent damage to seeds and seedlings and frost damage to seedlings have also caused many failures.

Successful plantings can now be made in the saltgrass and in some greasewood types. Experience has shown that these plants must be eradicated for successful artificial revegetation. Greasewood can be eliminated by wheatland plowing or similar methods. Saltgrass is more difficult to eradicate. The method which has given best results is to turn the sod completely under. This can best be done by moldboard plowing to a depth of 4 to 5 inches in the summer or fall, when the soil surface is dry. Spring planting has been best on wet alkali lands and late fall or early spring planting is superior on dry alkali soils. Planting procedures which place the seed in a shallow furrow or depression have given better results than drilling directly into soil surface.

Species adapted to wet alkali areas with a high water table are tall wheatgrass, alta fescue, yellow sweetclover, fivehook bassia, and Belvedere summercypress. Promising species, on areas with a low water table which dries out in summer, are Russian wildrye and crested wheatgrass. On some of these areas drought tolerance is more important than a tolerance to soil salts.

III. Seed Germination and Plant Growth under Natural Conditions

III-A. Date of planting in the fall at three locations

Results from the date of planting study established in the fall of 1958 were included in the 1959 Progress Report. Results from the fall of 1959 planting will be presented below but results from the fall of 1960 planting will not be determined until the spring and summer of 1961.

This study was established to determine when seeds of the selected species germinate in the fall and winter and to evaluate the advantages and disadvantages of early and late fall seedings. Seed germination in the fall and winter is further evaluated by comparing field germination with laboratory germination at near optimum temperatures and moisture.

Seed of four species from the 1959 crop were planted on four dates at three locations in the fall of 1959. Sites were located in Ephraim Canyon at elevations of 5,500 feet (Sorenson's Field), 7,000 feet (Majors Flat), and 8,850 feet (Headquarters Station). Seed lots used in this study were the same as those used in the following section on "Depth of Planting." Seeds in nylon mesh bags with 100 seeds of a single species per unit were planted at all sites on each of the following planting dates: September 23, October 7, October 21, and December 10, 1959. On each planting date seeds were placed under 3/4 inch of soil at three separate areas at each site. Three replications of all species were placed at each area. Two replications were treated with Orthocide 75, but one replication was not treated. As shown above, the last planting date was made at all sites on December 10, 1960. At this time no emergence could be seen from the three earlier plantings. At the two lower sites the soil was dry and at the upper area the soil was frozen.

The fall of 1959 was dry and cold at the two lower sites so that conditions were unfavorable for rapid seed germination. At the sagebrush site in the valley, snow was intermittent from early November to December 24. From December 24 to March 17 snow cover was continuous with snow depth varying from a minimum of 2.5 inches in early January to a maximum of 15 inches in late February. At the intermediate elevation, 7,000 feet, the area was covered with shallow intermittent snow in November and early December but was blanketed with snow from 9 to 28 inches from December 24 to March 25. At 8,850 feet the soil moisture was high from the middle of September to early November, but air and soil temperatures were very low. At this site, the surface soil was frozen in mid November and remained frozen until after March 21, 1960. Snow cover from early November to December 24 was shallow, with only 2 to 3 inches of snow on the soil during most of this period. Snow depth exceeded 20 inches from December 24 to May 2, 1960 with a maximum snow depth of 59 inches on February 29. Seeds planted on each of the four planting dates were removed from each of the three sites on three dates in the spring according to plant development at the site: Ⓐ early (February 10, March 4, and April 13, respectively); Ⓑ during expected period of rapid germination and growth at each elevation (April 5, April 15, and May 16, respectively); and Ⓒ the final removal date was made just as the soil was drying in the spring at that site (May 13, June 7, and June 17, respectively).

When the first sample was removed from the sagebrush site the snow was about 8 inches deep and the soil was moist and thawed. Germination of intermediate wheatgrass seed was marked in the first, second, and third planting dates with some shoots from the first planting date just showing above the soil surface. Grass and forb seeds from natural sources were also germinating and were frequently above the soil surface. Seed germination of smooth brome was much less than the intermediate wheatgrass. Many seeds of mountain brome were just beginning to germinate but only a few slender wheatgrass seeds from the first planting date had germinated.

As shown in table 1, when the first seed sample was removed from the intermediate elevation, seed germination of intermediate wheatgrass was high with many shoots above the soil surface. A few smooth brome shoots were also above the soil surface. Although over 90 percent of the mountain brome seeds had developed roots no shoots could be found on this date.

By April 13, when the first sample was removed from under 28 inches of snow at the upper site, the soil surface had partly thawed but deep soil was still frozen. Intermediate wheatgrass seedlings from the first planting date and a number of seeds from the second planting date had emerged but only a few from the third planting date had germinated and none of the seeds from the last planting date had germinated. Some of the seeds of smooth brome and mountain brome from the first and second planting dates had germinated but none of the slender wheatgrass seed had germinated.

Table 1 .--Percent germination from four dates of planting in the fall when seeds were removed at three dates in the winter or spring, depending on climatic conditions at the three sites and after subsequent laboratory germination of 31 days

	Sorenson's - 5,500'			Majors - 7,000'			Headquarters - 8,850'		
	Removal Date								
Pltg. Date	1st 2/10	2nd 4/5	3rd 5/13	1st 3/4	2nd 4/15	3rd 6/7	1st 4/13	2nd 5/16	3rd 6/17
Intermediate wheatgrass - when removed from field									
9/23	85.5	97.5	95.0	83.5	98.5	98.0	62.5	68.0	98.0
10/7	70.5	96.5	97.5	81.0	98.0	98.0	56.0	68.0	94.5
10/21	74.0	94.5	96.5	86.5	97.0	97.0	7.5	30.5	97.5
12/10	8.5	89.0	98.0	44.5	80.0	96.5	0.0	1.0	92.5
- after 31 days in laboratory									
9/23	97.5	97.5	95.0	95.0	98.5	98.0	94.0	97.5	98.0
10/7	94.5	96.5	97.5	95.5	98.5	98.0	95.5	99.0	96.5
10/21	96.5	94.5	96.5	97.0	97.0	98.0	96.5	97.5	97.5
12/10	87.5	93.5	98.0	91.5	95.5	98.5	98.5	94.0	98.0
Slender wheatgrass - when removed from field									
9/23	1.5	97.5	98.0	9.5	96.5	97.0	0.0	18.0	96.0
10/7	0.0	96.0	98.0	18.0	98.5	98.0	0.0	0.0	90.5
10/21	0.0	95.5	97.5	32.0	97.5	94.5	0.0	0.0	97.0
12/10	0.0	60.5	72.5	0.0	44.5	94.0	0.0	0.0	62.5
- after 31 days in laboratory									
9/23	54.5	97.5	98.0	51.5	97.0	97.0	97.0	96.0	98.5
10/7	9.5	97.0	98.0	73.5	98.5	98.0	79.0	94.0	98.5
10/21	24.5	96.0	97.5	78.5	97.5	94.5	91.0	99.0	97.0
12/10	16.0	78.0	77.5	15.5	89.5	96.0	76.5	89.5	80.5
Mountain brome - when removed from field									
9/23	66.0	99.5	99.5	97.5	98.0	99.5	2.5	28.5	67.5
10/7	16.0	98.0	97.5	97.0	99.0	98.5	0.5	2.5	44.5
10/21	38.0	96.0	98.0	97.0	97.5	97.0	0.0	0.0	33.0
12/10	25.5	92.5	95.5	81.0	87.0	94.5	0.0	0.0	9.5
- after 31 days in laboratory									
9/23	95.5	99.5	99.5	99.5	98.0	99.5	38.0	78.5	75.0
10/7	73.5	98.0	97.5	99.0	99.0	98.5	31.5	36.0	53.0
10/21	83.0	96.0	98.0	97.5	97.5	97.0	9.5	18.5	41.0
12/10	43.5	93.0	95.5	90.0	89.5	95.0	20.0	17.0	15.5
Smooth brome - when removed from field									
9/23	15.5	87.5	95.5	21.5	95.0	96.0	24.5	18.5	92.5
10/7	7.5	93.5	96.0	34.5	93.5	96.0	2.5	2.5	95.5
10/21	8.0	90.5	94.5	33.5	91.5	92.5	0.0	1.0	95.5
12/10	3.0	91.0	95.5	14.0	53.5	96.5	0.0	1.0	87.0
- after 31 days in laboratory									
9/23	93.0	88.0	95.5	96.5	95.0	96.0	93.0	94.5	93.5
10/7	94.0	94.5	96.0	97.5	94.0	96.0	93.5	93.5	97.5
10/21	95.5	93.0	94.5	92.0	92.0	92.5	94.5	93.0	96.0
12/10	89.5	92.0	95.5	93.0	91.0	97.0	90.5	91.0	92.5

On the second sampling date seeds of all species from all planting dates at the lower and intermediate sites had germinated or were germinating rapidly. At the upper site snow was just leaving on May 16 when the second sample was removed. The soil surface had thawed but deeper soil was still frozen. Some seeds of intermediate wheatgrass and smooth brome from all dates of planting had germinated but seeds of the native species, slender wheatgrass and mountain brome, from the third and fourth planting dates had not started to germinate.

The last samples were removed from each area just as the spring moisture was becoming depleted. As shown in figure 5, all species produced many healthy seedlings at the intermediate site. This was also true at the lower and upper sites. Additional germination in the laboratory was relatively small for the mountain brome seed removed from the upper site, indicating seed dormancy had not been fully broken.

In general, differences in date of planting were less than may occur when existing early fall conditions favor early fall germination. Intermediate wheatgrass and smooth brome seeds normally germinate as soon as moisture and temperatures are favorable. However, with the native species, conditions necessary to overcome the existing seed dormancy must be satisfied before seed germination can take place.

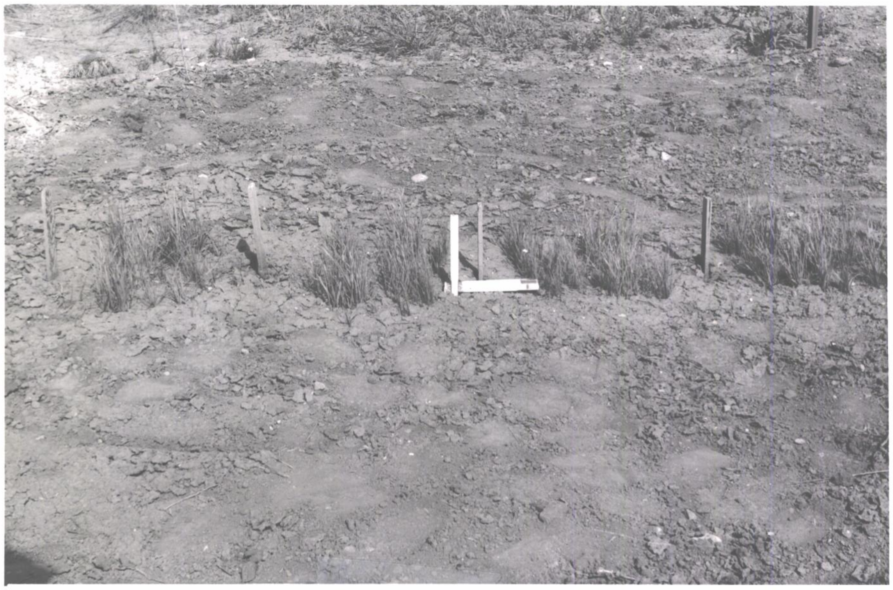


Figure 5.--Date of planting study at the 7,000 foot site just as the soil was drying in the spring and just before the last remaining nylon bags were removed from the soil on June 7, 1960 (60-18).

III-B . Depth of planting and seedling emergence

Seed of eight species were planted at three locations in Ephraim Canyon in the fall of 1959. Sites were located at elevations of 5,500 feet (Sorenson's Field), 7,000 feet (Majors Flat), and 8,850 feet (Headquarters Station). This study was established to provide information on ability of seed to germinate, depth of emergence of shoots, and seed dormancy at various depths below the soil surface.

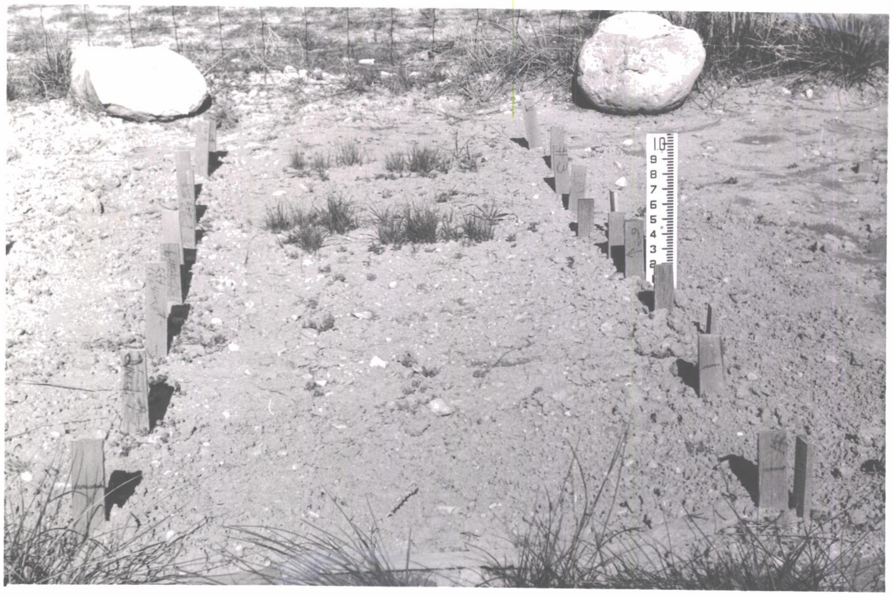
Species used are listed below:

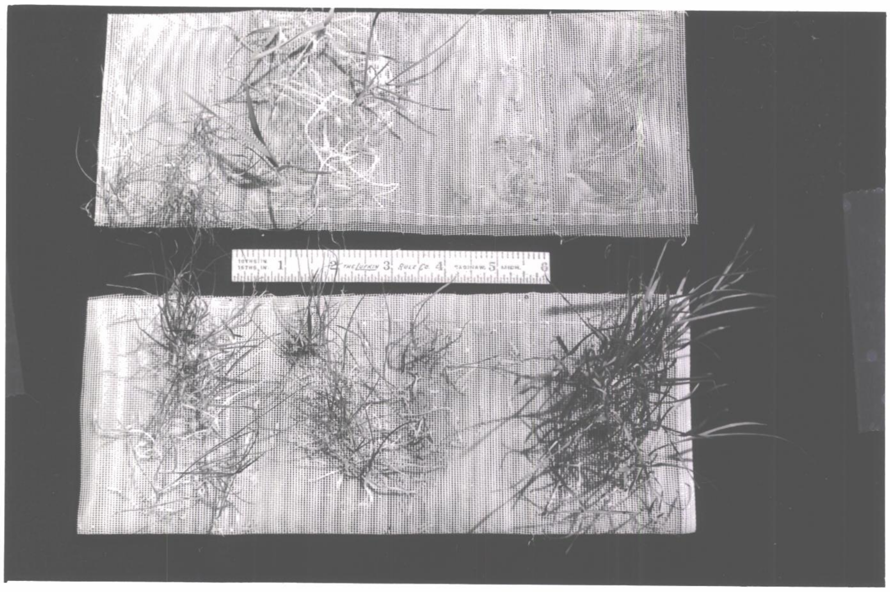
1. Agropyron desertorum - 1959 seed grown at Majors Flat.
2. Agropyron intermedium - 1959 seed grown on Frischknecht Farm, Sanpete County - progeny of P-2327.
3. Agropyron trachycaulum - 1959 collection of native seed, Ephraim Canyon, 9,400 feet.
4. Avena fatua, Siler Farm, Sanpete County, 1959 seed.
5. Bromus carinatus - 1959 collection of native seed, Ephraim Canyon, 10,000 feet.
6. Bromus inermis - 1959 seed, Headquarters Nursery in Ephraim Canyon.
7. Medicago (Rambler) commercial).
8. Hordeum (Winter Club) barley - commercial.

Seeds of all lots were thoroughly screened to remove all impurities and light seeds. Seeds were then separated into units containing 50 seeds or 100 full heavy seeds per unit. Part of the seeds used in the depth of planting study and all of the seeds used in the emergence study were treated with Orthocide 75 at recommended rates. Seeds used in the depth of planting study were placed in nylon bags with 100 seeds of a single species per bag except 50 wild oats seeds per bag were used because of the size. Openings in the bags were then closed and stitched to prevent seed loss. Seeds used in the emergence study were placed in packets with 50 seeds per packet to facilitate direct planting in the soil.

In the depth of planting study, seeds in bags were placed at the following depths: 1/2 inch, 1 inch, 2 inches, 4 inches, 6 inches, 1 foot, and 2 feet at each elevation. Two replications of seed treated with Orthocide 75 and one replication of untreated seed were planted at each depth to furnish information on damage to seeds and seedlings by soil organisms, but this information will not be discussed in this section.

Seeds from the 1/2-, 1-, and 2-inch depths were removed from the 5,500-foot site on May 4, 1960 (figures 6 and 7). Seed at depths of 4 inches, 6 inches, 1 foot and 2 feet were removed on June 7, 1960. As shown in table 2, all species had started to germinate at all depths before they were removed from the soil. Some additional germination of seeds in the germinator occurred with all species except the barley. Seed germination of crested wheatgrass, slender wheatgrass, and smooth brome was noticeably less at the deeper depths but differences in percent germination were small with intermediate wheatgrass, alfalfa, and barley. Some seedlings of wild oats from the 4-inch depth reached the soil surface. The nylon mesh bags in which the seeds had been planted frequently retarded the penetration of barley, wild oats, and alfalfa shoots but did not seriously retard shoot penetration of the five remaining grasses.





Figures 6 and 7.--The upper photo shows seedlings that have emerged from the nylon bags placed at a depth of 1/2-and 1-inch depths at the 5,500 feet elevation. The lower photo shows the nylon bags removed from the 1/2-inch depth with crested wheatgrass, barley, alfalfa, and wild oats in the upper bag and mountain brome, smooth brome, intermediate wheatgrass, and slender wheatgrass in the bottom row. (60-49 and 60-38)

Table 2.--Percent of seeds germinated, when removed from soil and after 31 additional days in a germinator (complete), that had been planted at three elevations in middle October 1959 at various depths and removed just as the soil was drying in the spring of 1960

		Desert wheatgrass			Intermediate wheatgrass			Slender wheatgrass			Alfalfa		
Depth		5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/
		Percent											
1/2 inch	Removed	88.5	88.0	65.0	95.5	99.0	92.0	92.0	99.0	79.5	81.5	78.5	89.0
	Complete	89.5	89.0	77.5	98.5	99.0	95.0	97.0	99.0	93.5	82.0	79.0	93.5
1 inch	Removed	94.0	97.5	89.5	97.5	97.5	94.0	99.0	97.0	91.5	78.5	86.0	82.5
	Complete	96.5	98.0	90.5	98.5	97.5	94.0	99.0	97.0	91.5	79.0	86.0	83.5
2 inch	Removed	94.0	95.0	85.0	97.5	98.0	91.0	95.0	98.5	95.0	82.0	82.5	80.5
	Complete	94.5	96.0	85.0	98.0	98.0	91.0	95.5	98.5	95.0	82.5	83.5	80.5
4 inch	Removed	16.5	96.5	82.5	95.0	99.0	91.5	93.5	96.5	94.5	82.0	80.5	89.5
	Complete	65.0	96.5	82.5	95.5	99.0	91.5	94.5	96.5	95.5	82.0	80.5	89.5
6 inch	Removed	28.0	80.0	89.5	97.0	97.0	95.0	74.0	97.0	97.0	84.5	77.5	82.5
	Complete	54.0	81.5	89.5	98.0	99.5	95.0	87.5	97.5	98.0	85.0	77.5	83.5
1 foot	Removed	21.5	97.5	92.5	94.5	96.5	94.5	4.5	90.5	98.5	82.0	78.0	76.0
	Complete	51.5	97.5	92.5	97.5	97.0	95.5	48.5	95.5	98.5	82.5	78.5	76.0
2 foot	Removed	26.0	87.5	87.0	92.5	94.5	88.5	32.5	54.5	93.0	89.5	78.0	79.0
	Complete	47.0	88.5	87.0	94.5	98.5	97.5	52.0	91.5	93.0	89.5	78.0	80.0

1/ Seed removed on May 4, 1960 at 1/2, 1, and 2 inch depths. Depths at 4 inches, 6 inches, 1 foot, and 2 feet were removed on June 7, 1960.

2/ Seeds were removed on May 27, 1960 at 1/2, 1, 2, and 4 inch depths. Depths at 6 inches, 1 foot, and 2 feet were removed on June 7, 1960.

3/ Seeds were removed on June 30, 1960 except the 1 and 2 foot depths were removed on July 1, 1960.

Table 2.--(continued)

		Barley			Mountain brome			Smooth brome			Wild oats		
Depth		5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/
		Percent											
1/2 inch	Removed	94.0	98.5	92.5	97.0	95.0	19.5	89.5	95.5	82.5	37.0	88.0	48.0
	Complete	94.0	98.5	92.5	97.0	95.0	27.5	93.5	95.5	87.5	37.0	88.0	56.0
1 inch	Removed	98.0	96.5	97.0	99.0	96.5	89.0	90.0	96.5	92.5	67.0	94.0	74.0
	Complete	98.0	96.5	97.0	99.0	96.5	89.0	90.0	96.5	92.5	70.0	94.0	76.0
2 inch	Removed	96.0	98.5	98.0	98.5	99.0	89.0	93.0	96.5	90.5	62.0	93.0	75.0
	Complete	96.0	98.5	98.0	98.5	99.0	89.0	93.0	96.5	90.5	62.0	93.0	75.0
4 inch	Removed	96.5	94.5	99.0	82.0	98.0	92.0	92.5	94.0	87.0	36.0	91.0	90.0
	Complete	96.5	94.5	99.0	82.5	98.0	92.0	92.5	94.5	89.5	43.0	91.0	90.0
6 inch	Removed	98.5	99.5	98.0	90.5	99.0	89.0	81.5	61.0	87.5	61.0	89.0	92.0
	Complete	98.5	99.5	98.0	93.0	99.0	89.0	92.5	94.5	92.0	67.0	89.0	92.0
1 foot	Removed	97.0	98.5	98.5	73.0	97.5	93.0	43.5	48.5	61.5	59.0	73.0	96.0
	Complete	97.0	98.5	98.5	73.0	97.5	93.0	94.0	83.0	84.5	65.0	73.0	96.0
2 foot	Removed	98.5	99.5	98.0	88.0	98.5	92.0	30.0	56.0	54.5	24.0	86.0	87.0
	Complete	98.5	99.5	98.0	88.0	99.5	92.0	90.0	97.5	88.0	38.0	86.0	87.0

1/ Seed removed on May 4, 1960 at 1/2, 1, and 2 inch depths. Depths at 4 inches, 6 inches, 1 foot, and 2 feet were removed on June 7, 1960.

2/ Seeds were removed on May 27, 1960 at 1/2, 1, 2, and 4 inch depths. Depths at 6 inches, 1 foot, and 2 feet were removed on June 7, 1960.

3/ Seeds were removed on June 30, 1960 except the 1 and 2 foot depths were removed on July 1, 1960.

At the 7,000-foot site, seeds buried at depths of 1/2, 1, 2, and 4 inches were removed on May 27 and seeds at 6 inches, 1 foot, and 2 feet were removed on June 7, 1960. At this site, seed germination of most species was nearly complete for all species except smooth brome and slender wheatgrass at the deeper depths.

At the 8,850-foot site, seeds buried at 1/2-to 6-inch depths were removed on June 30 and the 1-foot and 2-foot depths were removed on July 1, 1960 (figure 8). Additional seed germination in the laboratory was slight except smooth brome seed removed from the 1-foot and 2-foot depths.

The percent of seeds that had started to germinate prior to removal from the soil varied with species, site (elevation) and with depth. Variation in the depth of planting was much less than expected due to the rather high seed germination of all species. A large portion of the variation between sites and depths appears to be due to soil temperatures and soil moisture at various depths at each location.

Maximum shoot penetration found when the nylon bags were dug was a 7.5 inch shoot of wild oats from the 2-foot depth at the 7,000 feet site but the nylon mesh bags usually confined the shoots of this species to the bag. Maximum shoot penetration of mountain brome was 105 mm. and maximum penetration for intermediate wheatgrass and slender wheatgrass was about 95 mm.

In the emergence study, seed of the 8 species were planted in rows 25 inches long and 6 inches apart at depths of 1/2, 1, 2, 4, and 6 inches. Fifty seeds of a single species that had been treated with Orthocide were uniformly placed along each 25 inch row. Each species

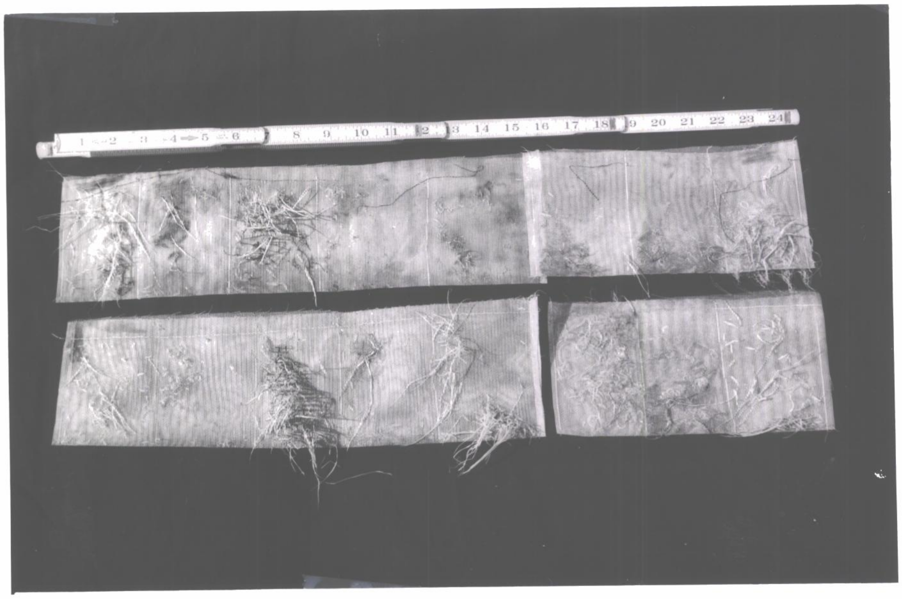
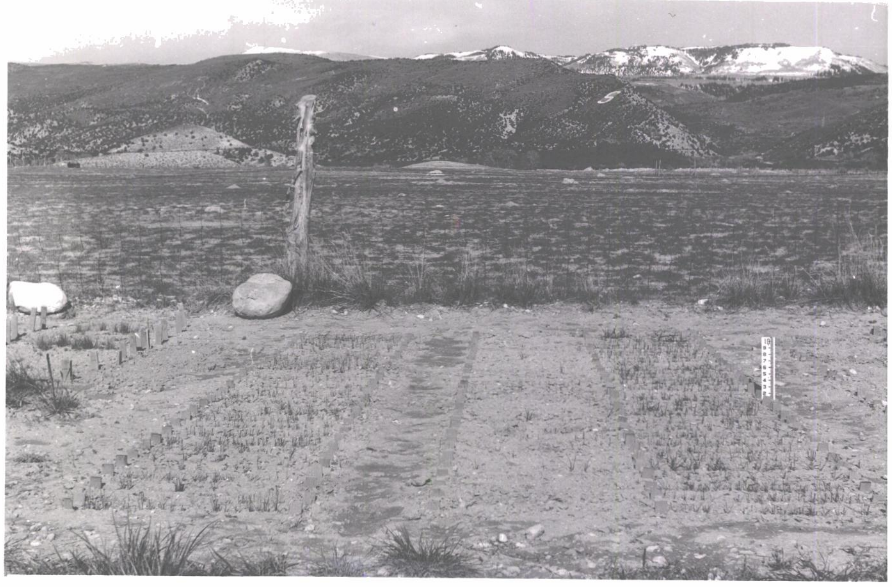


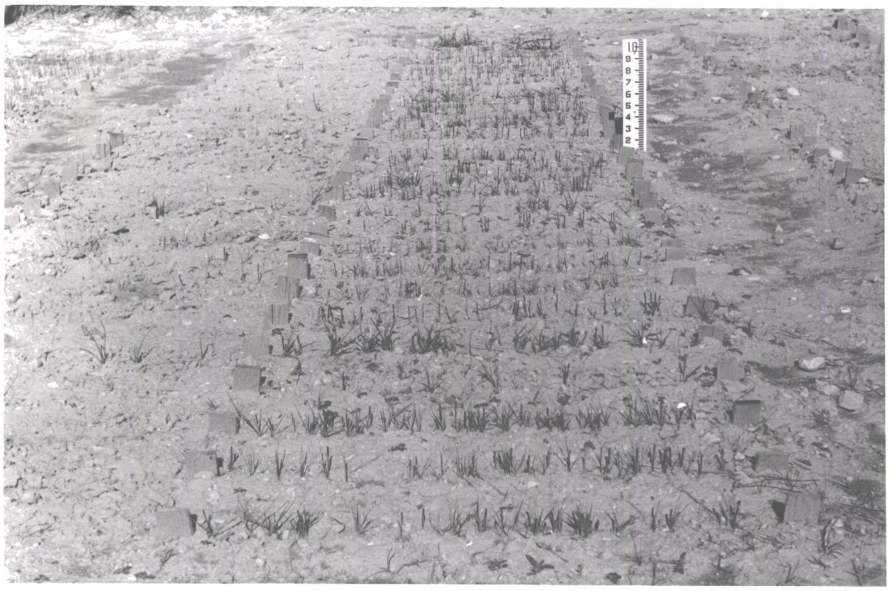
Figure 8.--Nylon bags removed from the 2-foot depth at the 8,850-foot site. Most of the seeds had germinated but many shoots had withered and many were broken when they were removed from the soil (60-168).

was replicated four times at each depth. Plantings at the 1/2 and 1 inch depths were made by making individual rows. The 2, 4, and 6-inch depths were planted in the bottom of trenches that were the proper depth and the original soil cover was replaced.

At each location seedling counts were made soon after snow left the area in the spring. Subsequent counts were made at frequent intervals during the spring periods when seedlings were emerging and at selected intervals later in the summer to check later emergence and mortality. All seedlings were marked with color-coded toothpicks so that development and mortality of individual plants could be followed (figures 9 and 10).

Maximum seedling emergence at all study sites was from the 1/2 and 1 inch depths as shown in table 3. Emergence from the 2 inch depth was much less than the shallower planting depths. Wild oats was the only species that emerged from the 4 inch planting depth at 5,500 feet. Wild oats was the only species emerging from the 4- and 6-inch planting depth at the 7,000-foot level. There was no seedling emergence from the 4-to 6-inch depth at the 8,850-foot site and no emergence from the 6-inch planting depth at the 5,500-foot site. Percent emergence was apparently influenced by many factors such as: soil moisture, soil temperature, species, soil crusting, seed dormancy, frost, size of seed, seedling vigor, and other factors.





Figures 9 and 10.--Seedling emergence from the 1-, 2-, and 1/2-inch depths from left to right can be seen in the upper photo at the 5,500-foot site. The lower photo shows a close-up view of the 1/2-inch depth (60-48 and 60-46).

Table 3 .--Average maximum percent seedling emergence from the soil from seeds of eight species planted at five depths at three locations in the fall of 1959

		Species							
Depth (Inches)	Location (Feet)	Crested Wheatgrass	Intermediate Wheatgrass	Slender Wheatgrass	Wild Oats	Barley	Mountain Brome	Smooth Brome	Alfalfa
		Percent							
1/2	5,500	78	76	62	20	34	80	66	57
	7,000	50	58	62	10	35	78	53	38
	8,850	19	62	32	2	10	12	26	51
1	5,500	58	54	68	12	14	74	66	45
	7,000	56	58	65	20	36	81	62	22
	8,850	21	56	34	7	20	29	34	33
2	5,500	2	4	8	8	1	26	4	2
	7,000	3	11	12	45	22	35	24	0
	8,850	8	6	8	3	12	12	5	1
4	5,500	0	0	0	9	0	0	0	0
	7,000	0	0	0	52	0	0	0	0
	8,850	0	0	0	0	0	0	0	0
6	5,500	0	0	0	0	0	0	0	0
	7,000	0	0	0	33	0	0	0	0
	8,850	0	0	0	0	0	0	0	0

III-C . *Fungi on seeds of six grasses, barley, and rambler alfalfa*

Failure of range plantings to produce good stands may be caused by many factors. Recent observations at this location have shown that seed or seedling diseases may seriously reduce seed germination or reduce the emergence of healthy seedlings and thus be important factors under certain conditions.

Seed or seedling diseases can be carried on the seed or in the soil. Grasses and small-seeded legumes are subject to seed-rot and damping-off caused by such soil-borne organisms as *Pythium*, *Rhizoctonia*, *Fusarium*, and *Phytophthora*. These parasitic fungi often attack the seed as it starts to germinate causing seedlings to rot before they emerge.

Various species of fungi causing seed or seedling rot have different requirements for growth. The variability of the growth habits of these fungi and climatic conditions makes it difficult to anticipate the severity with which disease may attack the seeds or seedlings. In general, increased organic matter and moisture make for more favorable growth conditions for fungi. It is known that the various species of fungi respond differently to differences in pH. An acid soil favors development of *Rhizoctonia*, while a neutral or alkaline soil favors *Pythium*. *Rhizoctonia* develops best in comparatively drier soils and at higher temperatures while *Pythium* develops best in wet soils at low temperatures.

Information on degree of infection by a specific fungus on four grasses at three elevations during the 1958-1959 seasons was presented in the 1959 report. This fungus was in an imperfect stage and identification has not been made at this time. Many other species of fungi have been encountered but they have not seriously reduced seed germination. Although many different fungi have been observed at high elevations, only limited damage to seeds, seedlings or living plants has been observed. Principal damage to living plants has been by snowmold that has damaged the Poa pratensis lawns at the Headquarters Station.

Studies similar to those made in the 1958-1959 period were repeated in the 1959-1960 period. Seeds were placed in small nylon bags with a single species in each bag at three elevations or sites in Ephraim Canyon: 5,500 feet (sagebrush type), 7,000 feet (mountain brush type), and 8,850 feet (aspen-fir type). In the "Date of Planting" studies, seeds of four species were buried at each site under 3/4-inch of soil on September 23, October 7, October 21, and December 21, 1959. At each site two replications were treated with Orthocide 75 at recommended rates and one or three replications, depending on date and elevation, were not treated. "Depth of Planting" studies were established at the three locations, with seven depths at each site, in mid October of 1954. At all locations one replication was treated with Orthocide 75 and one replication was not treated except at the sagebrush site where two replications were not treated. Eight species, including six grasses, barley, and rambler alfalfa were included in this study.

"Date of Planting" samples were removed from the sagebrush site on February 10, April 5, and May 13. Seeds treated with Orthocide were relatively free of all fungi and only four seeds from all treatments were visibly infected with the specific fungus under study. As shown in table 4 the percent of untreated seeds visibly infected with this fungus varied with species, planting date, and removal date. In general, percent of seeds infected with fungi was largest on the seeds planted early in the fall of 1959 and least on the last planting date. Percent of seed infected tended to increase with the later removal dates. Seeds of the domestic species, crested wheatgrass, intermediate wheatgrass, and smooth brome were infected much more than seed of the native species slender wheatgrass and mountain brome.

"Date of Planting" samples were removed from the mountain brush site on March 4, April 15, and June 7 and from the aspen-fir site on April 13, May 16, and June 17. Percent of seeds infected with fungi was much less at the mountain brush site than it was at the lower sagebrush site and no fungi were found on the seeds planted at the aspen-fir site.

"Depth of Planting" studies were removed from each site just as the soil was drying in the spring of 1959. At the sagebrush site the 1/2-inch and 1-inch and 2-inch depths were removed on May 4 and the 4-inch, 6-inch, 12-inch, and 24-inch depths were removed on June 7. At the mountain brush site, the seed planted at shallower depths was removed on May 27 except for the 6-inch, 12-inch, and 24-inch depths that were removed on June 7. At the aspen-fir site all depths were removed on June 30 or July 1, 1960.

Percent of seeds visibly infected with fungi in the "Depth of Planting" study varied with site, depth of planting, and species. As shown in table 5 fungi were most abundant at the lower site with only

Table 4 .--Percent of seeds of four species planted on four dates in the fall of 1959 at three sites that were visibly infected by a specific fungus on three dates in the spring of 1960

Date planted	Intermediate wheatgrass			Slender wheatgrass			Mountain brome			Smooth brome			
	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	Percent	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	
Sagebrush Site - 5,500 ft.													
	Removal Date			Removal Date			Removal Date			Removal Date			
	2-10	4-5	5-13	2-10	4-5	5-13	2-10	4-5	5-13	2-10	4-5	5-13	Ave.
9-23	56	60	63	3	0	1	12	25	18	85	86	92	41.8
10-7	10	40	75	1	2	1	3	8	8	79	87	77	32.6
10-21	14	75	66	1	0	0	4	8	20	76	77	86	35.6
12-10	0.3	1	1	0	0	0	1	0	0	0.3	13	10	2.2
Average	20.1	44.0	51.2	1.2	0.5	0.5	5.0	10.2	11.5	60.1	65.8	66.2	
Mountain Brush Site - 7,000 ft.													
	Removal Date			Removal Date			Removal Date			Removal Date			
	3-4	4-15	6-7	3-4	4-15	6-7	3-4	4-15	6-7	3-4	4-15	6-7	
9-23	0	0	0	0	0	0	0	0	0	0	2	0	0.2
10-7	0	1	0	0	0	0	0	0	0	5	6	4	1.3
10-21	7	2	1	0	0	0	0	0	0	7	15	4	3.0
12-10	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Average	1.8	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	3.0	5.8	2.0	
Aspen Fir Site - 8,850 ft.													
	Removal Date			Removal Date			Removal Date			Removal Date			
	4-13	5-16	6-17	4-13	5-16	6-17	4-13	5-16	6-17	4-13	5-16	6-17	
9-23	0	0	0	0	0	0	0	0	0	0	0	0	0.00
10-7	0	0	0	0	0	0	0	0	0	0	0	0	0.00
10-21	0	0	0	0	0	0	0	0	0	0	0	0	0.00
12-10	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Average	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00

a few seeds infected at the mountain brush site and no seeds were infected at the aspen-fir site. Fungi were most abundant on the domestic grasses smooth brome, intermediate wheatgrass, and desert wheatgrass (figure 11). A few seeds of the native grasses, mountain brome and slender wheatgrass were infected at the sagebrush site but seeds of barley, wild oats, and alfalfa seeds were not infected with this fungus. At the sagebrush site fungi was most abundant on seeds at the 2-inch, 1-inch, 1/2-inch, and 24-inch depths. Reasons for the decrease in fungi at the 4-, 6-, and 12-inch depths are believed to be closely related to the dry soil in comparison with either the deeper or shallower soils.

Seeds visibly infected with fungi usually did not begin to germinate. Where visible fungi developed after the seeds had started to germinate, the seedlings were usually abnormal and the shoot frequently shriveled and turned brown.

Treated and untreated seeds were again planted in the fall of 1960 in conjunction with the "Date of Planting" and the "Depth of Planting" studies. Additional plantings of treated and untreated seed of smooth brome, intermediate wheatgrass, and crested wheatgrass were planted at four additional locations in the sagebrush type.

Table 5 .--Percent of seeds of eight species planted at seven depths at three sites in the fall of 1959 that were visibly infected with a specific fungus in the spring of 1960

	Depth of Planting							
Species	1/2 inch	1 inch	2 inch	4 inch	6 inch	12 inch	24 inch	Average
	Percent							
Sagebrush Site - 5,500 ft.								
Desert wheatgrass	26	59	74	6	0	0	4	24.14
Intermediate wheatgrass	46	67	83	0	1	0	8	29.29
Slender wheatgrass	0	3	1	0	0	0	0	0.57
Wild oats	0	0	0	0	0	0	0	0.00
Mountain brome	9	8	25	0	1	0	5	6.86
Smooth brome	55	77	96	0	1	0	20	35.57
Barley	0	0	0	0	0	0	0	0.00
Alfalfa (Rambler)	0	0	0	0	0	0	0	0.00
Average	17.00	26.75	34.88	0.75	0.38	0.00	4.62	
Mountain Brush Site - 7,000 ft.								
Desert wheatgrass	0	1	0	0	0	0	0	0.14
Intermediate wheatgrass	0	0	1	2	2	1	0	0.86
Slender wheatgrass	0	0	0	0	0	0	0	0.00
Wild oats	0	0	0	0	0	0	0	0.00
Mountain brome	0	0	0	0	0	0	0	0.00
Smooth brome	0	0	0	0	0	1	4	0.71
Barley	0	0	0	0	0	0	0	0.00
Alfalfa (Rambler)	0	0	0	0	0	0	0	0.00
Average	0.00	0.12	0.12	0.25	0.25	0.25	0.50	
Aspen-Fir Site - 8,850 ft.								
Desert wheatgrass	0	0	0	0	0	0	0	0.00
Intermediate wheatgrass	0	0	0	0	0	0	0	0.00
Slender wheatgrass	0	0	0	0	0	0	0	0.00
Wild oats	0	0	0	0	0	0	0	0.00
Mountain brome	0	0	0	0	0	0	0	0.00
Smooth brome	0	0	0	0	0	0	0	0.00
Barley	0	0	0	0	0	0	0	0.00
Alfalfa (Rambler)	0	0	0	0	0	0	0	0.00
Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

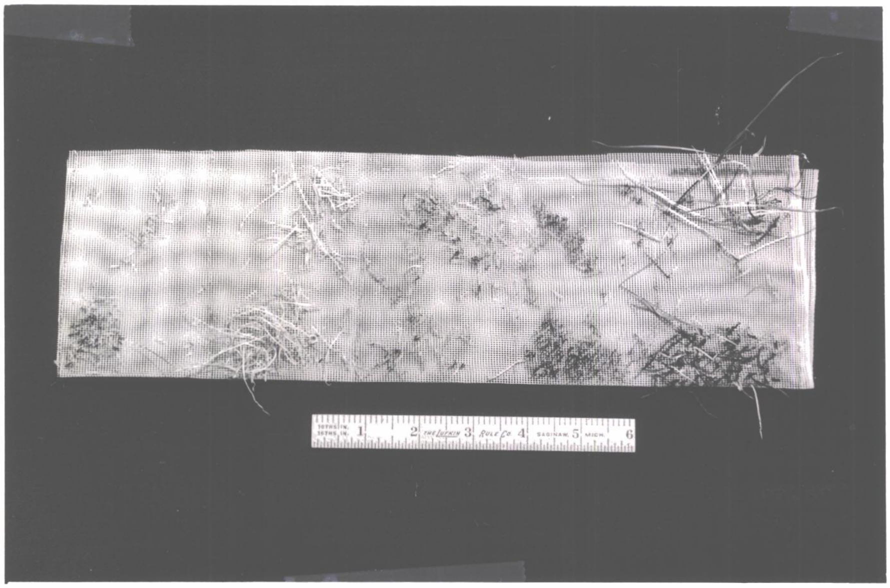


Figure 11.--This nylon bag containing five pockets was removed from the 2-inch depth at the sagebrush site on May 4, 1960. The first pocket on the left containing desert wheatgrass seeds, the third pocket containing intermediate wheatgrass seeds, and the fourth pocket containing smooth brome seeds were heavily infected with the black fungus which can be seen above. The second pocket contained vigorous seedlings of slender wheatgrass. The last pocket on the right contained seeds and some vigorous seedlings of mountain brome, but 25 percent of the mountain brome seeds were infected with the fungus (60-39).

III-D . Seed germination and seedling emergence studies at high elevations

Studies established in the fall of 1959 were very similar to studies established in the fall of 1958. Tests were made on 45 species or strains of grasses, forbs, and shrubs instead of the 36 species or strains used in 1958 studies.

Seeds used were freshly harvested from the 1959 crop except that one year or older seed lots of intermediate wheatgrass, slender wheatgrass, mountain brome, smooth brome, barley, and alfalfa were also included in this study. Where practical seeds were harvested from high elevation areas similar to the study sites. Species used and pertinent information on date and seed source are included in table 6.

Laboratory germination tests at 68 and 82°F. were made on all seed lots on September 18, 1959 and again on July 20, 1960 after storage at room temperature. All seed lots were treated with Orthocide 75, according to directions, prior to placement in the germinator since mold had developed on seeds of many species in earlier tests. Tests were made to determine the difference in seed germination soon after harvesting the 1959 seeds and germination after dry storage for about 1 year (10 months). Laboratory seed germination tests were also used as a control lot for seeds planted in the sacks and rows.

The two study areas are about 2 miles apart, but slope and enclosures are quite different: () Philadelphia Flat - is located on a wide near level terrace at an elevation of approximately 10,000 feet. This area is frequently snow covered from the first heavy snow in October or November, until the air temperature is relatively high the following May or early June, when frost danger is low. When dry or unfrozen soil is covered by snow in the fall, the soil may remain at or above freezing throughout the winter. This area is subjected to flooding during rapid snowmelt in the spring. Flooding may also cause a breakdown in the soil structure, which in turn may decrease aeration, reduce water holding capacity, and favor crusting. (2) Summit Enclosure - is on a west facing slope of approximately 8 percent at an elevation of 10,200 feet. Snow depth, during the winter period on this area, is usually less than on Philadelphia Flat, due to increased melting in the fall and spring, and wind action. Soil may be frozen during the winter. When the soil is bare or snow covering is shallow, alternate freezing and thawing may produce heaving, frost damage, or rapid drying of the surface soil around the seeds. Flooding has been observed, but does not appear to be a serious problem on this site.

Areas used in the fall of 1959 adjoined the 1958 study sites. Areas were prepared during the late summer of 1959. Areas used for the sack study were staked with poles over 8 feet long so that samples could be located after deep snow covered the ground.

Early snow on September 17, 1959 put down about 6 inches of snow on most of the plot areas. Additional snow in late September and early October kept a shallow snow cover on the soil until mid October when all south and west exposures and many level areas were free of snow. Subsequent storms in late October and early November covered the soil with about 8 inches of snow but this gradually melted, leaving south and west slopes bare and only a shallow snow cover on the level. Due to this shallow snow cover, snow was hauled to the Summit Enclosure on November 20, 27, and December 2 to keep the nylon bags covered with snow. Deep soil freezing took place on both study areas although the Philadelphia Flat area was covered with 5 to 10 inches of snow. On December 21 the Philadelphia Flat soil had frozen to a depth of 6 to 14 inches, depending on snow depth. Bare soil on the Summit had frozen to a depth of over 3 feet with concrete frost to a depth of 23 inches. Many large cracks had developed in the soil and one crack was 23 inches deep.

Snow depth continued to increase until early March when snow was 66 inches deep on Philadelphia Flat. Soil temperatures at the soil surface and 3/4-inch depth increased to about 32°F. on March 18 and occasionally reached 33°F. prior to snowmelt on May 31, 1960. Partial thawing of the soil to a depth of 3/4- to 1-inch was observed under the snow at both study areas. Snow depth increased rapidly in late May and the Summit area was nearly free of snow on May 25 and the Philadelphia Flat area was nearly free of snow on May 31.

This study was divided into two phases. In one phase, the germination of seeds in nylon bags, planted under snow or soil, on two dates of planting was checked at intervals during the winter and spring. In the second phase, seed of each species was planted in rows in the fall, and emergence and mortality counts were made at intervals during the following spring and summer.

One hundred seeds of a single species were placed in nylon bags and the bags were closed and stitched. Large seeds were placed in bags with a mesh opening about 1/20-inch square. Species with small seeds were placed in bags made from light weight nylon material with a fine mesh.

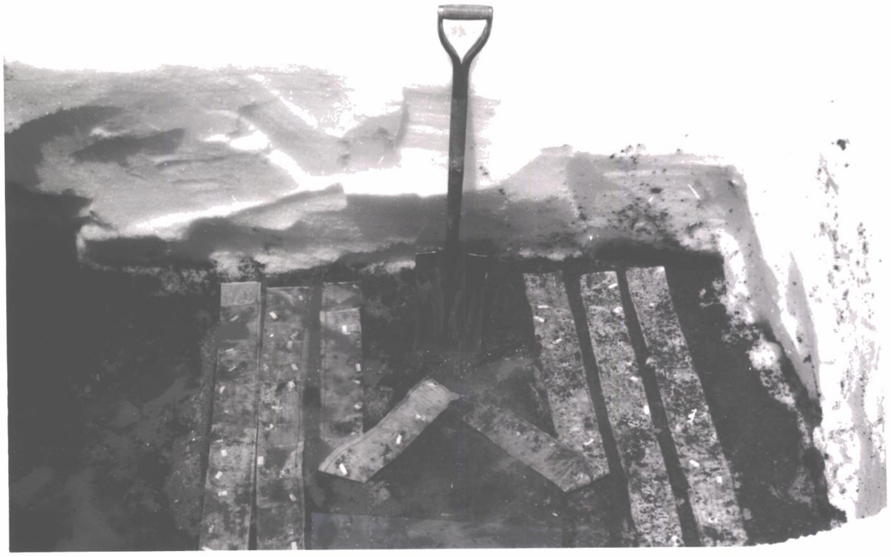
Snow depths on Philadelphia Flat in the winter of 1959-1960 are shown below:

Date	Snow Depth (Inches)
Sept. 17, 1959	6
Sept. 23, 1959	5
Oct. 12, 1959	Trace
Oct. 30, 1959	3
Nov. 3, 1959	6
Nov. 10, 1959	8
Nov. 18, 1959	6
Dec. 7, 1959	5
Dec. 21, 1959	10
Dec. 30, 1959	19
Jan. 29, 1960	28
March 1, 1960	66
March 30, 1960	61
April 25, 1960	46
May 16, 1960	25
May 20, 1960	28
May 25, 1960	19
May 29, 1960	14
May 31, 1960	10
June 1, 1960	Trace

Early fall (pre-snow) planting of seeds in bags were made under 3/4-inch of soil on September 22 on both areas. Additional plantings were made on the Summit Enclosure on November 2, after 5 inches of snow covered the area. Some seed samples were placed on the bare soil and others were buried under 3/4 inch of soil, but in each case the snow cover was replaced. Additional plantings were made on Philadelphia Flat on November 11 when the snow cover was 8 inches deep. Part of these samples were also placed directly on the soil surface and part were buried under 3/4-inch of soil and in each case the snow cover was replaced.

One replication of seeds from the pre-snow planting was removed from the Summit Enclosure on November 2 and from Philadelphia Flat on November 18. Seeds were packed in snow until seed germination counts were made in the laboratory. Subsequent removal of seeds in bags were made from Philadelphia Flat on March 1, April 22 (figures 12 and 13), June 1, June 13, and June 27, 1960.

Subsequent removal of seed in bags were made from the Summit Enclosure on May 18, June 9, and June 27, 1960. Seed germination on the check lot placed in the germinators on July 20, 1960 and on the sample removed from Philadelphia Flat on June 1, just as the snow was leaving the area are shown in table 6. All but 3 of the 45 seed lots in the pre-snow planting, removed on June 1, had started to germinate prior to removal and all but 5 of these same seed lots had started to germinate from the planting under 3/4 inch of soil after the permanent winter snow was on the ground. All but nine of the seed lots placed on the soil



Figures 12 and 13.--Seeds in nylon bags were removed from Philadelphia Flat at selected dates in the winter of 1959-1960. The upper photo shows the pit made in the snow to reach the bags on April 25. The lower photo shows the sample taken on June 1, 1960, just as the snow melted (60-13 and 60-83).

Table 6 .--Percent germination for seeds of 45 species or strains planted under 3/4 inch of soil in early fall, under 3/4 inch of soil after permanent winter snow, and placed on the soil surface after permanent snow on Philadelphia Flat when determined on June 1, 1960, just before snowmelt in the following spring

		Planting Treatment			
	Date	Early Fall	Permanent Snow		2/ Check
Species, Location, and Date of Collection	1/	Soil	Soil	Snow	Lot
		- - - -	Percent	- - - -	
Grasses					
Agropyron desertorum - Majors Flat. Aug. 6, 1959. El. 7,100 ft.	Removed	77.0	35.0	33.0	-
	Final	79.0	59.0	45.0	95.3
Agropyron intermedium - Frischknecht Farm. Sept. 5, 1958. El.5,500 ft.	Removed	97.0	81.0	84.0	-
	Final	98.0	88.0	95.0	98.0
Agropyron intermedium - Frischknecht Farm Aug. 24, 1959. El. 5,500 ft.	Removed	83.0	80.0	54.0	-
	Final	97.0	93.0	93.0	99.0
Agropyron trachycaulum - Dungeon Ephraim Can. Aug. 13, 1958. El. 9,400 ft.	Removed	90.0	63.0	43.0	-
	Final	92.0	96.0	93.0	91.0
Agropyron trachycaulum - Dungeon Ephraim Can. Aug. 26, 1959. El. 9,400 ft.	Removed	66.0	11.0	7.0	-
	Final	74.0	88.0	59.0	78.3
Alopecurus pratensis - Summit Enclosure. Aug. 17, 1959. El. 10,200 ft.	Removed	57.0	15.0	40.0	-
	Final	75.0	76.0	87.0	93.0
Arrhenatherum elatius - Summit Enclosure. Aug. 21, 1959. El. 10,200 ft.	Removed	59.0	94.0	95.0	-
	Final	72.0	96.0	95.0	93.0
Bromus carinatus - Cattle Pasture Ephraim Can. Aug. 14, 1958. El. 10,100 ft.	Removed	79.0	60.0	19.0	-
	Final	81.0	68.0	22.0	60.3
Bromus carinatus - Philadelphia Flat. Aug. 14, 1959. El. 10,000 ft.	Removed	48.0	34.0	8.0	-
	Final	55.0	46.0	9.0	37.0
Bromus inermis - Headquarters Ephraim Can. Sept. 8, 1958. El. 8,850 ft.	Removed	64.0	12.0	42.0	-
	Final	79.0	95.0	90.0	93.0
Bromus inermis - Headquarters Ephraim Can. Sept. 3, 1959. El. 8,850 ft.	Removed	20.0	4.0	35.0	-
	Final	53.0	89.0	95.0	95.7
Bromus tomentellus - Summit Enclosure. Aug. 17, 1959. El. 10,200 ft.	Removed	57.0	79.0	95.0	-
	Final	62.0	88.0	95.0	92.0
Dactylis glomerata - Summit Enclosure. Sept. 14, 1959. El. 10,200 ft.	Removed	40.0	17.0	77.0	-
	Final	85.0	99.0	91.0	94.0

Table 6.--(Continued)

		Planting Treatment			
		Early			2/
	Date	Fall	Permanent Snow		Check
Species, Location, and Date of Collection	1/	Soil	Soil	Snow	Lot
		- - - - - Percent - - - -			
Hesperochloa kingi - Buck Ridge Ephraim Can.	Removed	93.0	93.0	12.0	-
Aug. 14, 1959. El. 9,700 ft.	Final	93.0	96.0	84.0	87.0
Hordeum (Barley) - Winter club. Commercial	Removed	98.0	96.0	95.0	-
	Final	98.0	98.0	95.0	98.7
Stipa columbiana - Cattle Pasture Ephraim	Removed	47.0	26.0	0.0	-
Can. Aug. 26, 1959. El. 10,100 ft.	Final	55.0	33.0	50.0	17.7
Stipa lettermani - Summit Enclosure.	Removed	59.0	30.0	5.0	-
Aug. 31, 1959. El. 10,200 ft.	Final	63.0	68.0	48.0	20.7
Forbs and Shrubs					
Aquilegia coerulea - Philadelphia Flat	Removed	0.0	0.0	0.0	-
Aug. 3, 1959. El. 10,000 ft.	Final	97.0	96.0	87.0	78.7
Claytonia lanceolata - Philadelphia Flat.	Removed	34.0	41.0	95.0	-
July 3, 1959. El. 10,000 ft.	Final	34.0	42.0	95.0	0.0
Collomia linearis - Philadelphia Flat.	Removed	91.0	74.0	76.0	-
Aug. 4, 1959. El. 10,000 ft.	Final	91.0	75.0	76.0	0.3
Delphinium nelsonii - Philadelphia Flat.	Removed	80.0	78.0	41.0	-
July 26, 1958. El. 10,000 ft.	Final	80.0	78.0	41.0	0.0
Descurainia richardsonii incisa - Meadows	Removed	19.0	23.0	16.0	-
Ephraim Can. Aug. 12, 1959. El. 9,900 ft.	Final	19.0	23.0	21.0	2.3
Eriogonum neglectum - Philadelphia Flat.	Removed	85.0	81.0	96.0	-
Aug. 21, 1959. El. 10,000 ft.	Final	87.0	83.0	96.0	7.3
Erythronium grandiflorum - Philadelphia Flat.	Removed	91.0	82.0	76.0	-
July 28, 1959. El. 10,000 ft.	Final	93.0	83.0	76.0	0.0
Geranium richardsonii - Philadelphia Flat.	Removed	87.0	94.0	85.0	-
Aug. 17, 1959. El. 10,000 ft.	Final	88.0	97.0	87.0	77.7
Gilia pulchella - Philadelphia Flat.	Removed	66.0	73.0	25.0	-
Aug. 13, 1959. El. 10,000 ft.	Final	66.0	76.0	27.0	5.7

Table 6 .--(Continued)

Species, Location, and Date of Collection	Date 1/	Planting Treatment			
		Early Fall	Permanent Snow		2/ Check
		Soil	Soil	Snow	Lot
		- - - - - - -Percent - - - -			
Lesquerella utahensis - Alpine Summit. July 16, 1959. El. 10,200 ft.	Removed	9.0	0.0	0.0	-
	Final	32.0	15.0	11.0	27.7
Lomatium nuttallii - Philadelphia Flat. Aug. 17, 1959. El. 10,000 ft.	Removed	58.0	67.0	50.0	-
	Final	58.0	70.0	54.0	0.0
Lupinus alpestris - Philadelphia Flat. Aug. 14, 1959. El. 10,000 ft.	Removed	97.0	96.0	96.0	-
	Final	97.0	96.0	97.0	22.7
Madia glomerata - Philadelphia Flat. Sept. 14, 1959. El. 10,000 ft.	Removed	93.0	75.0	100.0	-
	Final	94.0	85.0	100.0	0.0
Mertensia leonardi - Cattle Pasture Ephraim Can. July 24, 1959. El. 10,100 ft.	Removed	90.0	83.0	85.0	-
	Final	91.0	87.0	85.0	1.0
Medicago sativa - Rambler (Commercial)	Removed	68.0	29.0	17.0	-
	Final	69.0	31.0	18.0	73.3
Orthocarpus tolmiei - Philadelphia Flat. Aug. 17, 1959. El. 10,000 ft.	Removed	35.0	18.0	35.0	-
	Final	35.0	20.0	37.0	0.0
Osmorhiza occidentalis - Philadelphia Flat. Aug. 31, 1959. El. 10,000 ft.	Removed	89.0	43.0	29.0	-
	Final	90.0	44.0	30.0	0.0
Penstemon rydbergii - Philadelphia Flat. Aug. 31, 1959. El. 10,000 ft.	Removed	76.0	80.0	79.0	-
	Final	77.0	97.0	88.0	0.0
Polygonum douglasii - Philadelphia Flat. Aug. 17, 1959. El. 10,000 ft.	Removed	82.0	70.0	74.0	-
	Final	82.0	72.0	74.0	0.3
Polemonium foliosissimum - Philadelphia Flat. Aug. 21, 1959. El. 10,000 ft.	Removed	92.0	10.0	0.0	-
	Final	92.0	16.0	1.0	0.0
Potentilla pulcherrima - Philadelphia Flat. Aug. 17, 1959. El. 10,000 ft.	Removed	0.0	0.0	0.0	-
	Final	93.0	91.0	92.0	97.0
Ribes montigenum -Philadelphia Flat. Aug. 26, 1959. El. 10,000 ft.	Removed	33.0	5.0	0.0	-
	Final	35.0	5.0	0.0	0.0

Table 6 .--(Continued)

		Planting Treatment			
		Early Fall	Permanent		2/ Check
Species, Location, and Date of Collection	Date 1/	Soil	Soil	Snow	Lot
Rumex mexicanus - Philadelphia Flat. Aug. 17, 1959. El. 10,000 ft.	Removed	0.0	0.0	0.0	-
	Final	23.0	10.0	10.0	1.7
Stellaria jamesiana - Philadelphia Flat. Aug. 10, 1959. El. 10,000 ft.	Removed	75.0	55.0	52.0	-
	Final	75.0	56.0	52.0	0.0
Taraxacum officinale - Philadelphia Flat. July 14, 1959. El. 10,000 ft.	Removed	7.0	1.0	0.0	-
	Final	88.0	52.0	39.0	88.3
Valeriana edulis - Philadelphia Flat. Aug. 17, 1959. El. 10,000 ft.	Removed	1.0	0.0	0.0	-
	Final	97.0	99.0	97.0	65.0
Viguiera multiflorum - Headquarters Ephraim Can. Sept. 14, 1959. El. 8,850 ft.	Removed	16.0	69.0	56.0	-
	Final	20.0	73.0	59.0	4.3
Viola nuttallii linguaefolia - Philadelphia Flat. July 27, 1959. El. 10,000 ft.	Removed	84.0	57.0	40.0	-
	Final	84.0	57.0	40.0	0.0

1/ Removed from soil and snow on 6/1/60 and Final after laboratory germination for 35 days.

2/ Check lot in germinator on 7/20/60.

soil surface after permanent winter snowfall had started to germinate before snow left the area on June 1. In general, germination of seed placed on the soil surface under the snow cover was slower to start than comparable seed lots placed under 3/4-inch of soil on the same planting date.

Phase 2, a study of seedling emergence and mortality was also conducted at Philadelphia Flat and at the Summit Enclosure. Row plantings with 100 seeds of a single species and 3 replications were made at Philadelphia Flat on September 22, 1958 and at the Summit Enclosure on September 28 and October 12, 1959. All species were planted at random, except that the two age groups of seed of intermediate wheatgrass, slender wheatgrass, mountain brome, and smooth brome were planted side by side. Large seeds were planted at a maximum depth of 2 cm. and small seeds were planted at a maximum depth of 1 cm. Each furrow was 5 feet long. Furrows were made by loosening the soil and shaping a shallow furrow with the bottom of a V-shaped piece of aluminum that was 5 feet 2 inches long. Uniform distribution of seed was obtained by first uniformly distributing the seed along a marked 5 foot row length on the upper side of the V-shaped piece of aluminum, then tipping the seed directly into the bottom of the furrow. Soil was placed over the seeds to the proper depth and firmed.

Seedling emergence and seedling mortality counts were made on each area about June 9 or 13, June 20, June 27, July 13, August 2, and August 25. On each date the newly emerged seedlings were marked with color-coded toothpicks (figure 14). Where seedlings had died

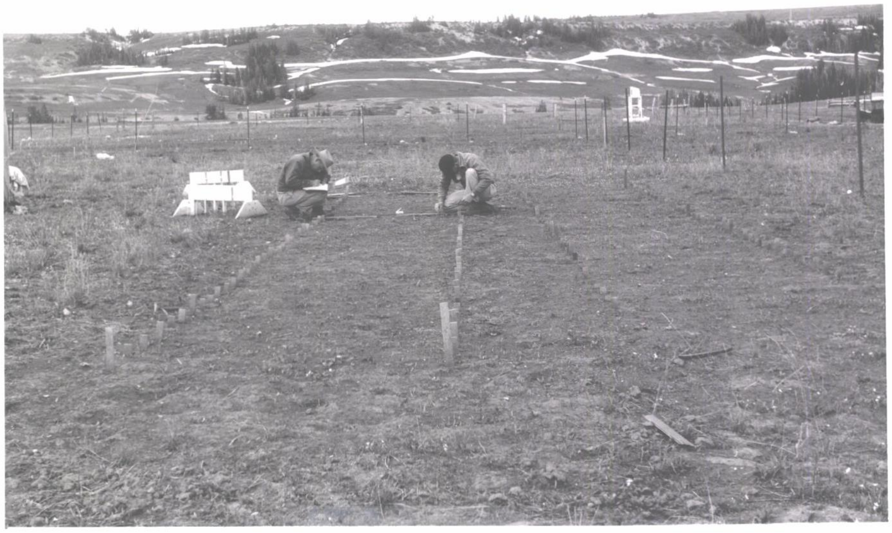


Figure 14.--Emerged seedlings were counted and marked with color-coded toothpicks so that date of emergence and mortality could be followed (60-110).

an uncolored toothpick was placed beside the colored toothpick. Total emerged seedlings and seedling mortality on June 9 or 13, July 13, and August 25 for all species are shown in table 7. Total seedling emergence on Philadelphia Flat was higher than at the Summit Enclosure but the difference was much less than in the 1958-1959 study when total emergence was approximately five times greater than at the Summit.

In general, the grasses produced better stands than the forbs and all grass species produced some seedlings at both sites. Three forbs and the shrub failed to produce a single seedling at Philadelphia Flat. Four forbs failed to produce a single seedling at the Summit Enclosure.

Additional mortality of plants from the 1959 planting had usually occurred between the last seedling counts made on September 21, 1959 and a count made in the second growing season (June 16, 1960). In general, mortality of grass plants was less than for the forbs. Seedlings from seed planted in the fall of 1958 were counted in the spring of 1960. Species producing the most seedlings in the second year were *Bromus carinatus*, *Agropyron trachycaulum*, *Delphinium nelsonii*, *Erythronium grandiflorum*, *Lomatium nuttallii*, *Osmorhiza occidentalis*, *Penstemon rydbergii*, *Stellaria jamesiana*, *Valeriana edulis*, and *Viola nuttallii*.

Annual species such as *Collomia*, *Madia*, and *Polygonium* produced abundant plants the second growing season. Figures 15 and 16 show the tarweed seedlings growing the second year on Philadelphia Flat. This photo also shows the heaving action on the dead *Madia* plants during the fall of 1959 and spring of 1960.

Table 7 .--Average field emergence per 100 fall planted seeds and seedling mortality at two locations on three dates: after spring snow-melt (6-9 or 6-13-60), mid-summer (7-13), and early fall (8-25)

Species		Locations					
		Philadelphia Flat			Summit Enclosure		
		Spring 6/13	Summer 7/13	Fall 8/25	Spring 6/9	Summer 7/13	Fall 8/25
		Percent					
Grasses							
Agropyron desertorum	Emergence	26.7	26.7	26.7	9.0	17.3	17.3
	Mortality		8.3	8.3		1.3	2.3
Agropyron intermedium 1958	Emergence	40.0	41.3	41.3	43.0	46.0	46.0
	Mortality		6.3	7.0		5.7	6.3
Agropyron intermedium 1959	Emergence	29.7	32.3	32.3	26.7	35.0	35.0
	Mortality		10.0	11.0		2.3	4.0
Agropyron trachycaulum 1958	Emergence	42.7	43.7	43.7	18.3	23.3	23.3
	Mortality		5.0	6.0		1.0	1.0
Agropyron trachycaulum 1959	Emergence	37.7	40.0	40.7	11.7	18.3	18.3
	Mortality		2.7	3.0		1.3	1.3
Alopecurus pratensis	Emergence	16.0	19.0	19.0	7.0	11.0	11.0
	Mortality		3.3	4.7		1.7	3.7
Arrhenatherum elatius	Emergence	49.7	51.0	51.0	15.3	23.0	23.0
	Mortality		5.7	7.3		4.7	4.7
Bromus carinatus 1958	Emergence	25.0	26.0	26.0	3.7	10.3	10.3
	Mortality		8.0	9.7		1.0	1.3
Bromus carinatus 1959	Emergence	21.7	24.7	24.7	4.3	9.3	9.3
	Mortality		5.0	6.0		0.3	2.0
Bromus inermis 1958	Emergence	11.7	14.0	14.0	14.7	22.7	22.7
	Mortality		3.7	4.7		2.7	4.3
Bromus inermis 1959	Emergence	10.3	17.0	17.0	15.0	22.3	22.3
	Mortality		1.7	2.0		1.3	2.7
Bromus tomentellus	Emergence	18.0	20.0	20.0	13.7	17.3	17.3
	Mortality		4.3	5.0		2.7	4.7
Dactylis glomerata	Emergence	21.3	24.7	24.7	2.7	13.0	13.0
	Mortality		2.7	3.7		1.7	1.7

Table 7 .—(Continued)

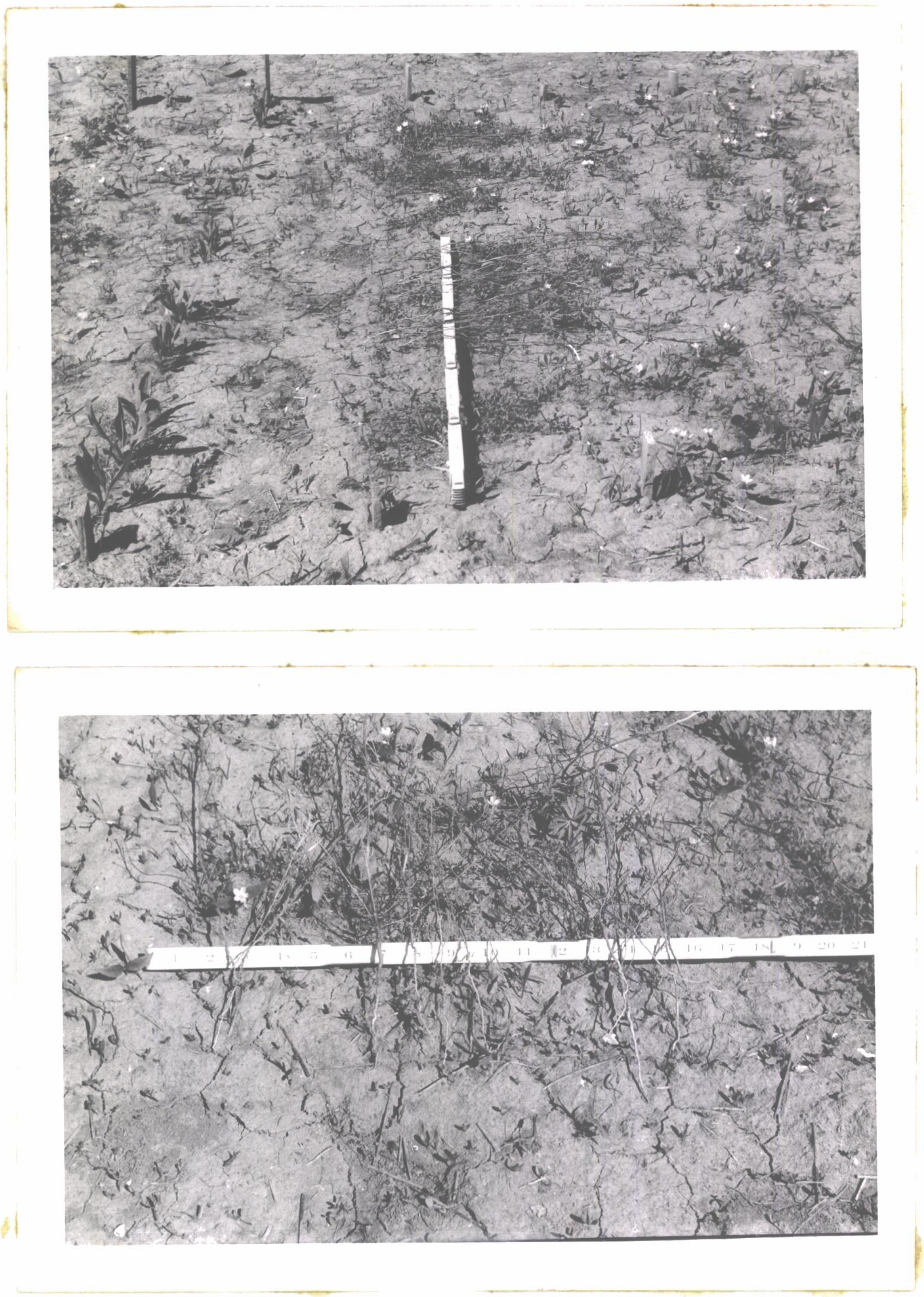
Species		Locations					
		Philadelphia Flat			Summit Enclosure		
		Spring 6/13	Summer 7/13	Fall 8/25	Spring 6/9	Summer 7/13	Fall 8/25
		Percent					
Hesperochloa kingi	Emergence	32.7	33.3	33.3	9.3	15.7	15.7
	Mortality		10.0	12.3		2.7	3.3
Hordeum (Barley)	Emergence	21.3	21.3	21.3	0.0	0.7	0.7
	Mortality		9.7	10.0		0.3	0.3
Stipa columbiana	Emergence	18.3	18.7	18.7	10.0	13.3	13.3
	Mortality		2.0	2.0		0.3	1.7
Stipa lettermani	Emergence	18.0	20.0	20.0	7.3	10.3	10.3
	Mortality		3.7	4.5		1.3	1.7
Forbs and Shrubs							
Aquilegia coerulea albiflora	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Claytonia lanceolata	Emergence	20.0	20.0	20.0	1.0	3.0	3.0
	Mortality		20.0	20.0		3.0	3.0
Collomia linearis	Emergence	32.3	33.0	33.0	18.3	21.7	21.7
	Mortality		2.7	3.7		4.0	4.3
Delphinium nelsonii	Emergence	0.0	0.3	0.3	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Descurainia richardsonii incisa	Emergence	0.0	0.7	0.7	0.0	0.7	0.7
	Mortality		0.3	0.3		0.7	0.7
Eriogonum neglectum	Emergence	0.0	14.3	14.3	13.7	14.7	14.7
	Mortality		1.7	3.0		1.7	3.3
Erythronium grandiflorum	Emergence	51.3	52.0	52.0	0.0	1.0	1.0
	Mortality		52.0	52.0		1.0	1.0
Geranium richardsonii	Emergence	30.0	30.7	30.7	22.0	23.7	23.7
	Mortality		6.0	6.0		5.3	6.3
Gilia pulchella	Emergence	8.7	12.3	12.3	12.0	13.0	13.0
	Mortality		0.3	2.0		7.7	7.7

Table 7.--(Continued)

Species		Locations					
		Philadelphia Flat			Summit Enclosure		
		Spring 6/13	Summer 7/13	Fall 8/25	Spring 6/9	Summer 7/13	Fall 8/25
		Percent					
Lesquerella utahensis	Emergence	13.3	14.0	14.0	6.3	7.3	7.3
	Mortality		11.7	12.0		4.7	5.0
Lomatium nuttallii	Emergence	36.3	37.7	37.7	1.0	1.7	1.7
	Mortality		4.3	7.3		0.3	0.3
Lupinus alpestris	Emergence	66.7	66.7	66.7	32.0	32.0	32.0
	Mortality		28.3	31.0		9.3	10.3
Madia glomerata	Emergence	50.3	52.0	52.0	37.3	39.0	39.0
	Mortality		0.3	0.7		5.7	6.0
Mertensia leonardi	Emergence	33.7	36.3	36.3	9.0	9.0	9.0
	Mortality		14.7	19.3		5.0	5.7
Medicago sativa	Emergence	0.0	1.3	1.3	6.7	10.3	10.3
	Mortality		0.3	0.3		4.3	4.3
Orthocarpus tolmiei	Emergence	0.0	3.0	3.0	0.3	0.3	0.3
	Mortality		0.0	0.0		0.0	0.0
Osmorhiza occidentalis	Emergence	23.7	24.0	24.0	2.0	2.0	2.0
	Mortality		4.3	6.0		2.0	2.0
Penstemon rydbergii	Emergence	0.0	3.3	3.3	0.0	0.0	0.0
	Mortality		1.7	2.0		0.0	0.0
Polygonum douglasii	Emergence	44.0	47.7	47.7	23.7	25.3	25.3
	Mortality		2.0	2.0		5.3	5.3
Polemonium foliosissimum albiflorum	Emergence	0.0	9.7	9.7	1.0	2.3	2.3
	Mortality		1.7	2.0		1.0	1.0
Potentilla pulcherrima	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Ribes montigenum	Emergence	0.0	0.0	0.0	0.0	0.3	0.3
	Mortality		0.0	0.0		0.3	0.3

Table 7 .--(Continued)

Species		Locations					
		Philadelphia Flat			Summit Enclosure		
		Spring 6/13	Summer 7/13	Fall 8/25	Spring 6/9	Summer 7/13	Fall 8/25
		Percent					
Rumex mexicanus	Emergence	0.0	0.0	0.0	3.0	3.0	3.0
	Mortality		0.0	0.0		1.3	1.3
Stellaria jamesiana	Emergence	6.7	8.0	8.0	14.0	14.3	14.3
	Mortality		4.3	4.3		12.3	14.3
Taraxacum officinale	Emergence	0.0	1.7	1.7	0.0	6.0	6.0
	Mortality		0.0	0.0		1.3	6.0
Valeriana edulis	Emergence	0.0	0.3	0.3	6.7	9.0	9.0
	Mortality		0.0	0.0		6.0	7.3
Viguiera multiflora	Emergence	0.0	17.0	17.0	11.3	13.7	13.7
	Mortality		0.7	1.0		6.3	6.7
Viola nuttallii linguaefolia	Emergence	28.7	31.0	31.0	5.0	9.3	9.3
	Mortality		7.3	10.3		0.3	1.7



Figures 15 and 16.--Many tarweed seedlings were present in the spring of the second year. These photos also show the heaving of the dead *Madia* plants that took place in the fall of 1959 and the spring of 1960 (60-143 and 60-144).

This study has shown that conditions necessary for seed germination vary with species. Seeds of some of the domestic grasses, crested wheatgrass, intermediate wheatgrass, and smooth brome, in particular, began to germinate as soon as moisture was adequate, even though temperatures around the seed often went below freezing at night. Seeds of some native and introduced grasses and forbs were slower to begin germinating under the low night temperatures and limited moisture. Typical of these species were *Alopecurus*, orchardgrass, *Geranium* and lupine. Seed germination in many other native plants remained low until seed dormancy was broken by the cold moist conditions existing in the unfrozen soil under the deep snow. Typical of these plants were mountain brome, slender wheatgrass, native *Stipa*, and tarweed. Seeds of another group did not germinate in the fall or winter while the soil was cool, but germinated after the soil warmed up in the spring, or germinated readily at 68 to 82°F. in the laboratory. Typical of these latter group were *Aquilegia* and *Potentilla*.

III-E. Seed germination and responses in snow, sand, and soil

This study was established to provide additional information on the factors which may limit or curtail germination, emergence, and establishment of grasses from fall plantings where a deep winter snow cover is normal. Treatments, procedures, and methods used were based on the studies conducted on Philadelphia Flat and Headquarters Station in the winters of 1956-1957, 1957-1958, and 1958-1959.

These studies demonstrated that some seed of introduced and native grasses began to germinate and grow in the thawing soil under a winter snow cover. Studies also demonstrated that viability of some of the remaining seed had been reduced. This was especially noticeable on areas that flooded during rapid spring snowmelt.

Seeds of four species, all harvested in 1959, were used in this study. Species used were: intermediate wheatgrass grown on the Frischknecht farm in Sanpete County, progeny of P-2327; a field collection of smooth brome grown in Ephraim Canyon at 8,850 feet; native slender wheatgrass from an elevation of 9,400 feet in Ephraim Canyon; and native mountain brome from an elevation of 10,000 feet in Ephraim Canyon. Seed of all species was harvested by hand and thoroughly cleaned. Seed was separated into units with 100 seeds of a single species per unit. Each unit was placed in a small nylon mesh bag and the bags were closed and stitched to prevent seed loss.

The study area was prepared during the late summer and fall of 1959. Five areas approximately 15 feet apart were cleared and staked so that sacks could be located after deep snow covered the site.

Five "planting" treatments were used in this study. These included placing sacks under 3/4-inch of native soil, placing sacks under 4 inches of native soil, placing seed on the soil surface under snow, planting under 3/4-inch of sand in a sand mound, and suspending sacks in the snow approximately 4 inches above the soil surface. Sand mounds were made by building a frame 3 feet square and 5 inches high of galvanized wire screen supported by lath stakes at all corners and at intervals along the sides. This frame was filled with builders sand. Wooden frames 2 feet square and 6 inches high were made without tops or bottoms. Ends of the frames were solid but the sides were partly open to allow lateral movement of snow. Four nylon cords were stretched across the top of the frame and the sacks were stitched to the nylon cords as shown in figure 17.

Plantings were made on December 10, 1959 when the snow depth averaged 6 inches. Soil was frozen to a depth of several inches with 1 inch of concrete frost but the deeper soil was granular with ice crystals in the interspaces. Plantings in the native soil were made in 3/4- and 4-inch pits dug prior to snowfall. Sacks were covered with unfrozen soil which had been removed from the pits in the late fall and stored in plastic bags for this purpose. Similar planting procedures were used for planting in the sand mounds under 3/4 inch of sand. Frames with bags in place were placed on the native soil with the bottoms of the bags suspended in the air about 4 inches above the soil surface. Bags placed on the soil surface were set in place and covered with snow to hold them in place. When all plantings were complete, a snow cover 10 inches deep was placed over the plot.

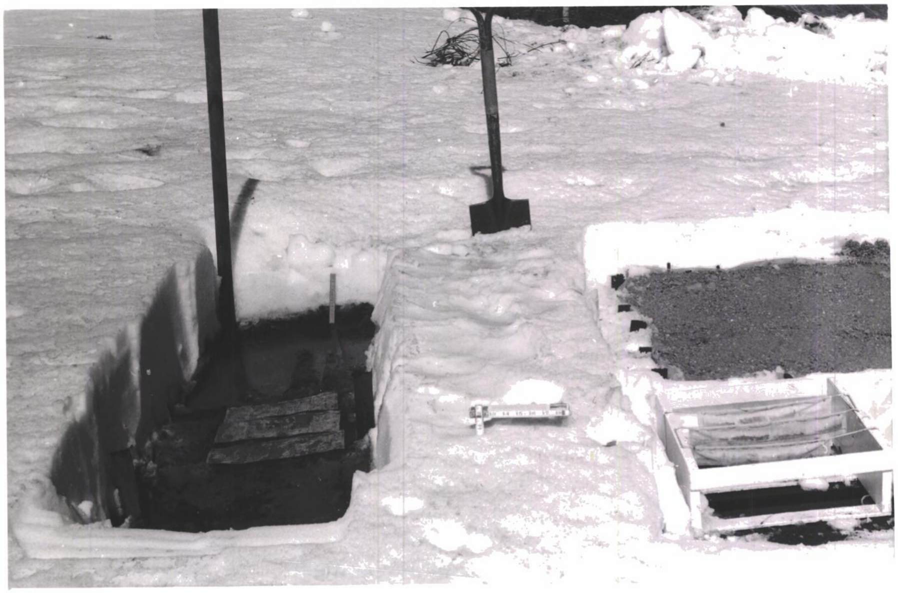


Figure 17.--The five planting treatments used in this study are shown on the May 11 sampling date, just before snow melted in the spring of 1960 (60-50).

Snow depth was shallow, 2 to 4 inches during November. Additional snow fell in early December but average depth remained near 6 inches until December 24 when snow depth reached 21 inches. Snow depth gradually increased and reached 31 inches on February 8. Heavy snows during February increased snow depth to 59 inches on February 29. Snow depth gradually decreased during March and April to 21 inches on April 25. Depth of snow varied between 23 and 17 inches until May 11. Warm days and nights from May 9 to May 13 produced rapid melting of the snow and the snow was gone from the plot area on May 14.

Maximum soil temperature at 3/4 inch were below freezing from November 12 to March 16. Minimum temperature of 17°F. was recorded on December 5, 1959 and temperatures remained below 30° until February 2, 1960. Maximum temperatures at the soil surface, in the sand, in the snow, and at a depth of 4 inches in the native soil seldom exceeded 32°F. prior to spring snowmelt.

The first sample of seed was removed on March 16 when the snow was still 58 inches deep. Some signs of gophers working were found but no damage to seeds or sacks was observed. Soil was starting to thaw in spots but about one-half of the soil over the bags was still frozen solid. The sand was not frozen and was very dry. Sacks in the snow were frozen. Some fungi could be seen on glumes of the seed but did not appear to damage the seed. Fungi was most abundant on seed that had been buried at 4 inches under the soil and least on seed that was suspended in the snow.

The second sample was removed on April 21 when the snow depth was still 24 inches. Soil was frozen at the surface and some frost was found in the soil at both 3/4 and 4 inches. Seed in the snow and in the sand were frozen when they were removed although some germination had started and all seeds had absorbed water. Bags in the third and fourth samples were removed on May 11. Soil at 3/4 and 4 inches was still mostly frozen and little or no germination had taken place. The fifth sample was removed on June 16, 1960.

As shown in table 8 no seeds had started to germinate on March 16 due to the low temperatures. By April 21 seeds of intermediate wheatgrass and smooth brome had started to germinate at all locations except the 4 inch depth. The native slender wheatgrass and mountain brome were slower to start germinating and seed dormancy had not been fully broken since germination in the laboratory was low. By May 11, when the snow was melting rapidly, additional germination of intermediate wheatgrass and smooth brome had taken place but the native slender wheatgrass seed was germinating only in the sand. This variation in germination is indicative of the variance that takes place from site to site.

On May 11, 1960, just a few days before the snow melted, additional seed samples were removed from the soil surface, sand mound, snow, 3/4-inch soil, and 4-inch soil depths. Seeds in nylon bags were taken to the laboratory where they were dried and stored at room temperatures. After 2 months seeds were removed from the bags and examined under a microscope. Seeds that had started to germinate were separated from

Table 8 .--Percent germination in seeds of four grasses placed in snow, under 3/4 inch sand, on soil surface, under 3/4 inch soil, and under 4 inches of soil, after a permanent winter snow was on the ground when removed on three dates, just as the soil thawed (3/16), after soil thawed (4/21), and just before spring snowmelt (5/11)

Sampling Date		Planting Location				
		Sand	Snow	Surface	3/4 inch Soil	4 inch Soil
		- - - - - - - - - -	- -	Percent	- - - - - - - - - -	- -
	Intermediate wheatgrass					
3/16/60	On removal	0.0	0.0	0.0	0.0	0.0
	Complete	97.7	92.0	95.3	91.0	90.3
4/21/60	On removal	7.0	0.7	13.0	4.7	0.0
	Complete	94.0	93.0	92.7	92.7	91.7
5/11/60	On removal	35.3	2.0	13.3	2.0	0.0
	Complete	88.0	93.7	87.0	87.7	86.7
	Slender wheatgrass					
3/16/60	On removal	0.0	0.0	0.0	0.0	0.0
	Complete	17.3	23.3	35.0	28.0	26.7
4/21/60	On removal	1.3	0.0	0.0	0.0	0.0
	Complete	46.7	55.7	56.3	76.0	78.0
5/11/60	On removal	6.3	0.0	0.0	0.0	0.0
	Complete	41.0	36.3	37.7	46.0	58.0
	Mountain brome					
3/16/60	On removal	0.0	0.0	0.0	0.0	0.0
	Complete	3.3	12.7	14.0	9.3	13.7
4/21/60	On removal	0.0	0.0	2.0	1.3	0.0
	Complete	22.7	1.7	6.7	25.3	16.3
5/11/60	On removal	28.7	0.0	0.0	0.0	0.0
	Complete	33.3	0.0	3.0	9.7	13.7
	Smooth brome					
3/16/60	On removal	0.0	0.0	0.0	0.0	0.0
	Complete	87.7	89.0	88.0	87.0	86.0
4/21/60	On removal	4.7	1.7	13.3	3.7	0.0
	Complete	86.0	89.3	88.0	89.0	86.7
5/11/60	On removal	13.3	6.7	7.3	0.3	0.0
	Complete	89.3	88.3	89.7	87.0	86.3

those that had not produced a visible radicle or shoot. All seeds were placed on moist sand in small plastic dishes and germinated at 68 to 82°F. for an additional 34 days. Seeds that had germinated or started to germinate prior to removal again absorbed water. Roots on some of these seeds firmed and appeared to be living, but many of them disintegrated in 1 to 4 days. Some of the seeds that had produced visible roots prior to drying developed a shoot but did not produce another root. As shown in table 9 many of the native mountain brome and slender wheatgrass seeds did not germinate in the field or during the 40 day period in the germinator but still appeared to be good seeds that were dormant.

Table 9.--Subsequent germination of seed of four species which was placed in snow on soil surface, under 3/4 inch of sand, under 3/4 inch of soil, and 4 inches of soil after permanent snowfall and removed prior to snowmelt in the spring; dried and stored at room temperature for 2 months and compared with germination of fresh seed from stock supplies

Location	Total No. of seeds	Total additional	Healthy seedling	None	Apparent good seed remaining
		- - - - -Percent	- - - - -	- - - - -	- - - - -
Intermediate wheatgrass					
Laboratory - stock seed	300	99.0	99.0	1.0	0.0
In Snow	300				
Visible germination	10	30.0	30.0	70.0	0.0
No visible germination	290	87.6	87.6	12.4	1.0
Sand - 3/4 inch	300				
Visible germination	100	16.0	16.0	84.0	1.0
No visible germination	200	67.5	67.5	32.5	2.0
Soil Surface Under Snow	300				
Visible germination	68	30.9	25.0	69.1	1.5
No visible germination	232	87.1	87.1	12.9	0.9
Soil - 3/4 inch	300				
Visible germination	3	33.3	33.3	66.7	0.0
No visible germination	297	95.3	95.3	4.7	0.0
Soil - 4 inch	300				
Visible germination	0	-	-	-	-
No visible germination	300	92.7	92.7	7.3	0.0
Slender wheatgrass					
Laboratory - stock seed	300	78.3	78.3	21.7	21.0
In Snow	300				
Visible germination	0	-	-	-	-
No visible germination	300	45.7	45.7	54.3	13.0
Sand - 3/4 inch	300				
Visible germination	20	25.0	25.0	75.0	0.0
No visible germination	280	47.5	47.5	52.5	14.3
Soil Surface Under Snow	300				
Visible germination	0	-	-	-	-
No visible germination	300	64.7	64.7	35.3	9.0
Soil - 3/4 inch	300				
Visible germination	0	-	-	-	-
No visible germination	300	63.0	63.0	37.0	7.3
Soil - 4 inch	300				
Visible germination	0	-	-	-	-
No visible germination	300	87.3	87.3	12.7	0.3

Table 9 .--(Continued)

Location	Total No. of seeds	Total additional	Healthy seedling	None	Apparent good seed remaining
		Percent			
Mountain brome					
Laboratory - stock seed	300	37.0	37.0	63.0	63.0
In Snow	300				
Visible germination	0	-	-	-	-
No visible germination	300	4.0	4.0	96.0	88.3
Sand - 3/4 inch	300				
Visible germination	59	0.0	0.0	100.0	7.3
No visible germination	241	1.2	1.2	98.7	87.1
Soil Surface Under Snow	300				
Visible germination	0	-	-	-	-
No visible germination	300	1.3	1.3	98.7	88.7
Soil - 3/4 inch	300				
Visible germination	0	-	-	-	-
No visible germination	300	4.0	4.0	96.0	86.7
Soil - 4 inch	300				
Visible germination	0	-	-	-	-
No visible germination	300	3.3	3.3	96.7	90.0
Smooth brome					
Laboratory - stock seed	300	95.7	95.7	4.3	0.3
In Snow	300				
Visible germination	1	0.0	0.0	100.0	0.0
No visible germination	299	76.6	76.6	23.4	0.0
Sand - 3/4 inch	300				
Visible germination	35	0.0	0.0	100.0	0.0
No visible germination	265	73.6	73.6	26.4	0.0
Soil Surface Under Snow	300				
Visible germination	29	0.0	0.0	100.0	0.0
No visible germination	271	64.9	64.9	35.1	0.0
Soil - 3/4 inch	300				
Visible germination	1	0.0	0.0	100.0	0.0
No visible germination	299	82.9	82.9	17.1	0.0
Soil - 4 inch	300				
Visible germination	0	-	-	-	-
No visible germination	300	93.3	93.3	6.7	0.0

IV. Depleted Sites at High Elevations

IV-A. Uniform study for seeding depleted sites on western range

Plans to establish a uniform study were first made at the Range Society Meetings held at Great Falls in January 1957. This study was conducted at six locations, as follows: Bozeman, Montana; Ephraim, Utah; La Grande, Oregon; Logan, Utah; Pullman, Washington; and Reno, Nevada. A general plan of study was made from the composite suggestions by Dr. Keller and the field men located at the locations shown above. A. C. Hull acted as coordinator, and assembled this material into study plan form.

Plantings were made on Forest Service land within two enclosures constructed by the Forest Service for this study. The two areas are only about 2 miles apart, but slope and exposure are quite different:

1. Philadelphia Flat - is located on a wide near level terrace at an elevation of approximately 10,000 feet. This area is frequently snow covered from the first heavy snow in October or November until the air temperature is relatively high the following May or early June when frost danger is low. When dry or unfrozen soil is covered by snow in the fall, the soil may remain at or above freezing throughout the winter. This area is subjected to flooding during rapid snowmelt in the spring. Flooding may also cause a breakdown in the soil structure which in turn may decrease soil aeration, reduce water holding capacity and favor crusting.

2. Summit Enclosure - is on a west facing slope of approximately 8 percent at an elevation of 10,200 feet. Snow depth during the winter period on this area is usually less than on Philadelphia Flat due to increased melting in the fall and spring and wind action. Soil may be frozen during the winter. When the soil is bare or snow covering is shallow, alternate freezing and thawing may produce heaving, frost damage, or rapid drying of the surface soil around the seeds. Flooding has been observed but does not appear to be a serious problem on this site. The first plantings were made on one area at each location according to plan in the fall of 1957 and spring of 1958. Subsequent plantings at this site were made in the fall of 1958, spring and fall of 1959, and in the fall of 1960. Additional spring plantings will be made after the snow melts in 1961. This report will include the third year results from the 1957-1958 plantings, the second year's result from the 1958-1959 plantings, and the first year's results from the 1959-1960 plantings. Progress reports for 1958 and 1959 contain data for the 1957-1958 and 1958-1959 periods, respectively.

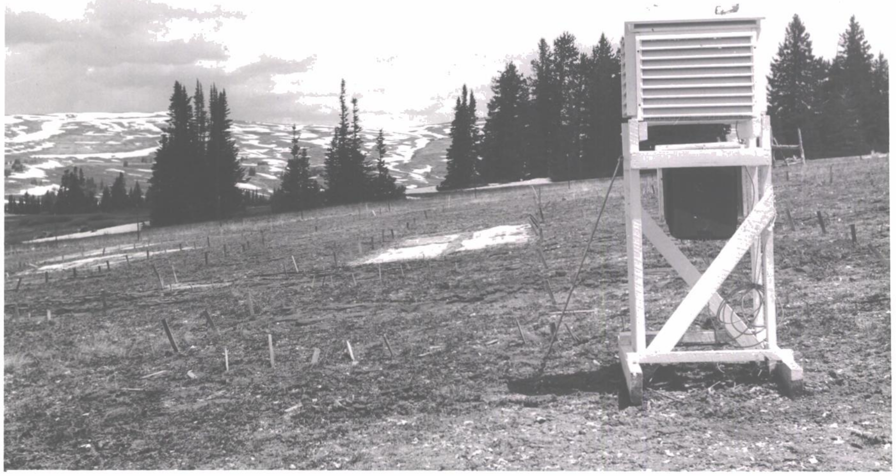
Major treatments included nine seedbed treatments applied on the contour and five fertilizer treatments applied up and down the slope at right angles to seedbed treatments. Seedbed treatments and fertilizer treatments applied or to be applied in each of the 4 years are listed below.

A. Seedbed treatments	1st Year 1957-1958	2nd Year 1958-1959	3rd Year 1959-1960	4th Year 1960-1961
1. Plow fall - summer fallow - plant next fall	x	x	x	
2. Plow fall - preparatory crop in fall - plant next fall	x	x	x	
3. Plow fall - plant in fall	x	x	x	x
4. Valley soil - plant in fall	x	x	x	x
5. Plow fall - plant in fall-1/2" sawdust	x	x	x	x
6. Plow fall - transplants	x	x	x	x
7. Plow fall - 1/4" contour furrows - plant in fall	x	x	x	x
8. Plow fall - plant spring	x	x	x	x
9. Check - no seedbed preparation or treatment	x	x	x	x
10. Plant fall - spray 4 lbs. 2,4-D in spring	x	x	x	
11. Spray 4 lbs. 2,4-D in spring - plant in fall	x	x	x	
12. Spray 4 lbs. 2,4-D in spring-plant spring			x	
13. Plow fall - plant fall and cover seed with sand			x	x
B. Fertilizer treatment				
1. Nitrogen - 100# per acre N	x	x	x	
2. Phosphorus - 200# per acre P_2O_5	x	x	x	
3. Nitrogen plus phosphorus	x	x	x	
4. Nitrogen, phosphorus, potash plus minor elements	x	x	x	x
5. Check	x	x	x	x

Plot areas for the 1959-1960 studies were plowed in August 1959. Fall plantings and fertilizer treatment were applied on two replications at each site on October 5 and 6. Spring plantings were made on June 6, 1960. As shown above, all treatments used in the 1957-1958 and 1958-1959 planting, plus two additional treatments were included. Species and seed sources used in the two previous plantings were used except that a winter barley "Winter Club" was planted to provide the nurse crop on the preparatory crop treatment areas.

The 7-day thermograph at Summit was moved from this area on October 19, 1959 and replaced on May 20, 1960, 4 days before snow melted from the plot area in the spring (figure 18). Figure 19 shows the 31-day thermograph at Philadelphia Flat that remained in operation yearlong. At both locations standard air temperatures and temperatures under 3/4 inch of soil were taken. At the Summit additional temperatures were taken at 6 inches above the soil surface and 1/4 inch under the soil. At Philadelphia Flat the third temperature unit was placed on the soil surface while snow covered the area but it was moved to a depth of 1/4 inch below the soil surface after spring snowmelt.

An early snow came on September 17, 1959 and additional storms in late September and early October moistened the soil but the wet soil made fall plantings difficult. The study areas were relatively free of snow from October 11 to November 2. Intermittent snow covered the Summit plot area until the latter part of December when a heavy storm put down a permanent winter snow. At Philadelphia Flat a shallow snow cover from 3 to 10 inches covered the soil from November 2 to the latter



Figures 18 and 19.--Thermographs were recording air and soil temperatures at both study areas. The 7-day unit at Summit was operated from just before spring snowmelt to late fall (60-103). The 31-day unit on Philadelphia Flat was operated throughout the year (60-75).

part of December when snow depth increased to 18 inches. Low air temperatures during November and December resulted in heavy freezing of the soil. On December 21 the soil on Philadelphia Flat was frozen to a depth of 6 to 14 inches, depending on the depth of snow above the soil. On the Summit area a King tube was driven to a depth of 3 feet. The soil was frozen with the first 23 inches frozen solid (concrete frost) and the lower 13 inches granular with numerous ice crystals.

Snow depth had increased to 27 inches on January 29, 1960 and to 66 inches by March 1, 1960. On the Summit area the snow depth had dropped to 16 inches but subsequent storms kept the snow depth over 14 inches until May 18. Snow melted from the area on May 24 and 25 (figure 20). On Philadelphia Flat the snow depth had dropped to 14 inches on May 29 and was nearly gone from the study area on June 1. Considerable frost action in the soil from about May 25 to June 3 produced a loose duff at the soil surface that was about 1 inch deep.

At Philadelphia Flat rapid snowmelt on June 1, 1960 (figure 21) exposed most of the area. By June 3 snow was gone from the plot and soil surfaces were beginning to dry with a slight crust. Frost action following snowmelt in addition to the frozen soil at a depth of 1 inch kept the soil at Philadelphia Flat from baking and forming a hard crust during the spring of 1960.

Spring plantings were made on June 6 at both the Summit and Philadelphia Flat. Spraying was not done because of an approaching storm which fell on June 6 to 8. Soil was still moist at the surface at both locations, alfalfa seedlings could be seen in the buffer plots as well as grass seedlings on all plots. Many seedlings were above ground and visible on June 9 and 11. Plots were sprayed at both Philadelphia Flat and Summit on June 13. The soil at Philadelphia Flat began to crust about June 14.

Seedling counts were made on June 22 and August 16 on both Philadelphia Flat and the Summit Enclosure (tables 10 and 11). The number of plants per foot of row during the second growing season on plots planted in the fall of 1958 and spring of 1959 are shown in table 12. Number of plants per foot of row during the third growing season on plots planted in the fall of 1957 and spring of 1958 are shown in table 13. Yield per acre on stands that were in the second and third growing season are shown in tables 14 and 15.

Fertilizers did not appear to improve stand establishment or increase herbageproduction at either site (tables 16 and 17). Native slender wheatgrass and mountain brome have consistently produced better seedling stands than the domestic grasses but these species are relatively short-lived. Fair to good stands of smooth brome, intermediate wheatgrass, pubescent wheatgrass, and artic Agropyron have been obtained, as shown in tables 18 and 19. On old nearby studies smooth brome and similar long-lived grasses that spread vegetatively have been superior.

This study has demonstrated that success or failure of a seeding may be determined by one condition on one site and another condition on an adjacent area. In general, treatments that remove the native condition and provide some protection for adapted species have been satisfactory. Treatments that have been consistently best at Philadelphia Flat are valley soil, sawdust muldh, and contour furrows.

Table 10 .--Number of plants per foot of row on 10 treatments on two dates during the 1960 seedling year at Philadelphia Flat

	Fall 1959								Spring 1960		
Species	Drill F-59 Spray S-60	Drill	Contour furrows	Sawdust + N	Cover seed with sand	Spray S-59 Drill F-59	Summer fallow	Straw mulch	Spray S-60 Drill S-60	Drill	Avg.
					June 22, 1960						
Slender wheatgrass	2.21	3.52	3.07	2.60	4.17	2.06	2.84	1.64	0.02	0.14	2.23
Tall oatgrass	0.56	0.91	0.79	0.50	0.59	0.66	0.56	0.30	0.03	0.03	0.49
Mountain brome	2.48	4.85	3.23	2.17	3.52	3.34	3.66	2.47	0.06	0.11	2.59
Smooth brome	1.13	2.61	1.71	0.79	1.89	1.08	1.27	0.78	0.21	0.93	1.24
Red fescue	1.27	2.59	2.12	1.30	2.56	1.30	2.22	1.59	0.00	0.05	1.50
Average	1.53	2.90	2.18	1.47	2.55	1.69	2.11	1.36	0.06	0.25	1.61
					Aug. 16, 1960						
Slender wheatgrass	1.65	2.45	2.44	2.62	2.82	1.25	1.80	0.55	0.03	0.16	1.58
Tall oatgrass	0.14	0.66	0.62	0.47	0.51	0.23	0.21	0.16	0.03	0.07	0.31
Mountain brome	1.89	3.55	2.54	2.16	2.91	1.84	2.61	0.71	0.10	0.34	1.86
Smooth brome	0.85	1.59	1.34	0.70	1.10	0.48	0.66	0.17	0.15	0.67	0.77
Red fescue	0.21	0.86	0.53	0.58	0.80	0.43	0.50	0.03	0.00	0.08	0.40
Average	0.95	1.82	1.49	1.31	1.63	0.85	1.16	0.32	0.06	0.26	0.98

Table 11 .—Number of plants per foot of row on 10 treatments on two dates during the 1960 seedling year at Summit Enclosure

Species	Fall 1959								Spring 1960		
	Drill F-59 Spray S-60	Drill	Contour furrows	Sawdust + N	Cover seed with sand	Spray S-59 Drill F-59	Summer fallow	Straw mulch	Spray S-60 Drill S-60	Drill	Avg.
	June 22, 1960										
Slender wheatgrass	0.46	2.83	1.81	1.95	16.11	1.51	2.53	1.42	0.00	0.05	2.87
Tall oatgrass	0.20	0.86	0.67	0.15	0.65	0.33	0.28	0.30	0.03	0.34	0.38
Mountain brome	0.27	2.12	2.27	1.39	4.09	0.65	0.89	0.82	0.01	0.02	1.25
Smooth brome	0.56	1.75	1.21	0.80	5.04	0.85	1.24	0.94	0.60	0.98	1.40
Red fescue	0.13	1.36	0.58	1.02	1.32	0.37	0.76	0.53	0.00	0.07	0.61
Average	0.32	1.78	1.31	1.06	5.44	0.74	1.14	0.80	0.13	0.29	1.30
	Aug. 16, 1960										
Slender wheatgrass	0.17	2.39	1.53	1.73	10.85	0.62	2.41	0.55	0.08	0.41	2.07
Tall oatgrass	0.00	0.75	0.44	0.27	0.42	0.08	0.15	0.03	0.01	0.39	0.25
Mountain brome	0.08	2.32	1.77	1.72	3.54	0.46	0.93	0.30	0.06	1.29	1.25
Smooth brome	0.27	1.37	0.93	0.71	3.65	0.50	1.05	0.17	0.27	0.65	0.96
Red fescue	0.00	1.39	0.72	1.19	1.44	0.05	0.58	0.00	0.00	0.12	0.55
Average	0.10	1.65	1.08	1.12	3.98	0.34	1.03	0.21	0.08	0.57	1.02

Table 12 .—Number of plants per foot of row on 10 treatments during the second growing season at Philadelphia Flat and Summit Enclosure

	Fall 1958									Spring 1959	
Species	Drill spray 2/	Drill 2/	Valley soil 2/	Contour furrow 2/	Sawdust + N 2/	Sawdust 2/	Spray drill 1/	Summer fallow 1/	Straw mulch 1/	Drill 2/	Average
	Philadelphia Flat - August 16, 1960										
Slender wheatgrass	0.64	3.26	5.50	2.50	3.57	3.67	0.58	2.52	1.60	1.29	2.51
Tall oatgrass	0.00	0.00	0.25	0.00	0.17	0.15	0.00	0.04	0.00	0.00	0.06
Mountain brome	0.65	2.79	2.38	2.88	2.85	2.45	0.66	2.42	1.90	0.97	2.00
Smooth brome	0.01	1.46	5.75	0.67	1.99	2.15	0.02	0.96	0.22	0.52	1.38
Red fescue	0.05	0.00	1.00	0.04	0.83	0.85	0.00	0.04	0.04	0.00	0.28
Total	1.35	7.51	14.88	6.09	9.41	9.27	1.26	5.98	3.76	2.78	6.23
Average	0.27	1.50	2.98	1.22	1.88	1.85	0.25	1.20	0.75	0.56	1.25
	Summit Enclosure - August 16, 1960										
Slender wheatgrass	0.09	0.94	0.25	0.86	1.02	1.60	0.04	0.40	0.06	0.25	0.55
Tall oatgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mountain brome	0.00	0.10	0.50	0.19	0.02	0.20	0.00	0.16	0.00	0.02	0.12
Smooth brome	0.00	0.65	0.00	0.42	0.80	1.05	0.00	0.14	0.00	0.71	0.38
Red fescue	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01
Total	0.12	1.69	0.75	1.47	1.84	2.85	0.04	0.70	0.06	1.01	1.06
Average	0.03	0.34	0.15	0.29	0.37	0.57	0.01	0.14	0.01	0.20	0.21

1/ Plants on one replication
2/ Average number of plants on two replications

Table 13 .—Number of plants per foot of row on seven treatments during the third growing season at Philadelphia Flat and Summit Enclosure

Species	Planted Fall 1957						Spring 1958	Total	Average
	Drill spray	Drill	Valley soil	Contour furrows	Sawdust + N	Sawdust	Drill		
Philadelphia Flat August 16, 1960									
Slender wheatgrass	0.44	1.94	4.00	1.96	1.90	3.00	0.88	14.12	2.02
Tall oatgrass	0.00	0.00	0.50	0.00	0.00	0.00	0.16	0.66	0.09
Mountain brome	0.22	1.30	4.25	2.42	2.36	2.80	1.18	14.53	2.08
Smooth brome	0.08	0.00	1.50	0.00	0.04	0.00	0.20	1.82	0.26
Red fescue	0.24	0.00	1.00	0.00	0.06	0.00	0.02	1.32	0.19
Total	0.98	3.24	11.25	4.38	4.36	5.80	2.44	32.45	4.64
Average	0.20	0.65	2.25	0.87	0.87	1.16	0.49	6.49	0.93
Summit Enclosure August 16, 1960									
Slender wheatgrass	0.10	0.02	0.00	0.28	1.34	1.50	0.16	3.40	0.49
Tall oatgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mountain brome	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smooth brome	0.00	0.00	0.00	0.00	0.18	0.40	0.64	1.22	0.17
Red fescue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.10	0.02	0.00	0.28	1.52	1.90	0.80	4.62	0.66
Average	0.02	0.00	0.00	0.06	0.30	0.38	0.16	0.92	0.13

Table 14 .--Average oven dry yield in pounds per acre for planted species during the second growing season and existing native species on the check plots at Philadelphia Flat and Summit Enclosure

	Fall - 1958									Spring 1959		Buffer F-1958	
Planted Species	Drill Spray 1/	Drill 1/	Contour furrows 1/	Sawdust + N 1/	Sawdust 1/	Spray Drill 2/	Summer fallow 2/	Preparatory crop 2/	Transplants 1/	Drill 1/	Check 1/	Species 3/	Yield 1/
					Philadelphia Flat - August 16, 1960								
Slender wheatgrass	193	485	616	1066	938	260	980	287	-	231	-	Agin^2	326
Tall oatgrass	0	0	0	47	7	0	11	0	-	0	-	Agsp	317
Mountain brome	249	754	896	1234	963	414	1274	306	-	174	-	Agtr^2	192
Smooth brome	2	464	168	713	642	13	480	99	144	150	-	Alpr	2
Red fescue	4	0	2	106	21	0	4	4	-	0	-	Dagl	127
Native species											1062 4/		
					Summit Enclosure - August 16, 1960								
Slender wheatgrass	93	887	501	690	204	36	250	11	-	224	-	Agin^2	150
Tall oatgrass	0	0	0	0	0	0	0	0	-	0	-	Agsp	874
Mountain brome	0	54	63	4	7	0	43	0	-	4	-	Agtr^2	16
Smooth brome	0	497	175	626	168	0	88	0	692	567	-	Alpr	2
Red fescue	5	0	0	0	0	0	0	0	-	5	-	Dagl	7
Native species											682		

1/ Average yield for two replications
2/ Yield for one replication
3/ Agin^2 = Agropyron intermedium; Agtr^2 = A. spp.; Agsp = A. spp.; Alpr = Alopecurus pratensis, and Dagl = Dactylis glomerata
4/ Geri 50%; Ardi 10%; Agtr 15%; Brca 5%; Brin 10%; and other 10%

Table 15 .—Oven dry yield in pounds per acre for planted species during the third growing season and existing native species on the check plots at Philadelphia Flat and Summit Enclosure

	Fall - 1957						Spring - 1958			Buffer F-1957	
Planted Species	Drill spray	Drill	Valley soil	Contour furrows	Sawdust + N	Sawdust	Drill	Transplants	Check	1/ Species	Yield
				Phil. Flat - Aug. 16, 1960							
Slender wheatgrass	158	1338	2861	985	2170	1736	158	-	-	Agin^2	0
Tall oatgrass	0	0	13	0	0	0	29	-	-	Agtr^2	0
Mountain brome	197	1063	2035	1925	1306	653	317	-	-	Alpr	0
Smooth brome	7	0	2362	0	18	0	170	976	-	Dagl	0
Red fescue	11	0	7	0	5	0	2	-	-	Feru	0
Native species									1175		
				Summit - Aug. 16, 1960							
Slender wheatgrass	89	54	0	150	960	268	72	-	-	Agin^2	80
Tall oatgrass	0	0	0	0	0	0	0	-	-	Agtr^2	36
Mountain brome	0	0	0	0	0	0	0	-	-	Alpr	0
Smooth brome	0	0	0	0	129	57	572	199	-	Dagl	0
Red fescue	0	0	0	0	0	0	0	-	-	Feru	0
Native species									404 2/		

1/ Agin^2 = Agropyron intermedium; Agtr^2 = A. spp.; Alpr = Alopecurus pratensis; Dagl = Dactylis glomerata, and Feru = Festuca rubra.

2/ 55% Taof; 10% Agtr; 10% Stle; 10% Acla; 5% Ardi; 5% Popu; 5% others.

Table 16 .--Number of plants per foot of row by fertilizer treatments on various seedling treatments on two dates during the seedling year on Philadelphia Flat

	Fall 1959									Spring 1960		
Fertilizer	Drill F-59 Spray S-60	Drill	Contour furrows	Sawdust + N	Sawdust	Cover seed with sand	Spray S-59 Drill F-59	Summer fallow	Straw mulch	Spray S-60 Drill S-60	Drill	Average 1/
						June 22, 1960						
Check - None	1.51	2.60	1.93	1.24	1.95	2.09	1.65	2.20	1.46	0.08	0.24	1.50
Nitrogen	1.42	2.74	2.02	1.43	-	2.52	1.60	2.29	1.16	0.10	0.24	1.55
Phosphorus	1.45	3.14	2.36	1.18	-	2.50	1.84	1.92	1.44	0.04	0.42	1.63
N + P	1.66	3.20	2.32	1.88	-	2.94	1.66	1.66	1.22	0.07	0.22	1.68
Complete	1.61	2.80	2.29	1.63	-	2.68	1.69	2.48	1.50	0.03	0.14	1.69
Average	1.53	2.90	2.18	1.47	—	2.55	1.69	2.11	1.36	0.06	0.25	1.61
						Aug. 16, 1960						
Check - None	0.89	1.70	1.33	1.06	1.87	1.49	0.97	1.19	0.32	0.03	0.22	0.92
Nitrogen	0.87	1.63	1.39	1.24	-	1.40	0.68	1.18	0.34	0.02	0.20	0.89
Phosphorus	0.92	1.95	1.71	1.12	-	1.51	1.03	1.02	0.36	0.13	0.34	1.01
N + P	1.06	1.80	1.43	1.55	-	2.24	0.84	1.00	0.33	0.06	0.32	1.06
Complete	1.00	2.03	1.61	1.56	-	1.50	0.71	1.39	0.27	0.07	0.24	1.04
Average	0.95	1.82	1.49	1.31	-	1.63	0.85	1.16	0.32	0.06	0.26	0.98

1/ Sawdust not included in average.

Table 17 .--Number of plants per foot of row by fertilizer treatments on various seedling treatments on two dates during the seedling year on Summit Enclosure

	Fall 1959									Spring 1960		
Fertilizer	Drill F-59 Spray S-60	Drill	Contour furrows	Sawdust + N	Sawdust	Cover seed with sand	Spray S-59 Drill F-59	Summer fallow	Straw mulch	Spray S-60 Drill S-60	Drill	Average 1/
						June 22, 1960						
Check - None	0.38	1.82	1.28	1.46	1.49	6.07	0.62	0.95	0.90	0.05	0.29	1.38
Nitrogen	0.37	1.87	1.40	0.91	-	4.24	0.83	0.78	0.56	0.05	0.41	1.14
Phosphorus	0.29	1.74	1.44	1.17	-	4.01	0.62	1.34	0.83	0.27	0.19	1.19
N + P	0.21	1.58	1.28	0.80	-	5.45	0.87	1.60	1.21	0.19	0.27	1.35
Complete	0.37	1.91	1.14	0.97	-	7.44	0.77	1.03	0.51	0.08	0.30	1.45
Average	0.32	1.78	1.31	1.06	-	5.44	0.74	1.14	0.80	0.13	0.29	1.30
						Aug. 16, 1960						
Check - None	0.08	1.64	1.14	1.25	1.68	4.48	0.31	0.79	0.24	0.02	0.46	1.04
Nitrogen	0.14	1.80	1.15	1.26	-	3.28	0.30	0.83	0.13	0.02	0.89	0.98
Phosphorus	0.18	1.80	1.12	1.50	-	3152	0.26	1.24	0.21	0.28	0.50	1.06
N + P	0.04	1.52	0.99	0.77	-	4.12	0.49	1.38	0.39	0.05	0.56	1.03
Complete	0.08	1.46	0.99	0.84	-	4.50	0.35	0.88	0.08	0.05	0.45	0.97
Average	0.10	1.65	1.08	1.12	-	3.98	0;34	1.03	0.21	0.08	0.57	1.02

1/ Sawdust not included in average.

Table 18.—Number of plants per foot of row by species and by fertility treatment on the Drill Fall Plots at Philadelphia Flat and Summit Enclosure for three consecutive fall plantings (1957 - 1959)

	Philadelphia Flat					Summit Enclosure				
Species	Seedling year	Second growing season	Third growing season	Total	Average	Seedling year	Second growing season	Third growing season	Total	Average
Slender wheatgrass	2.45	3.26	1.94	7.65	2.55	2.39	0.94	0.02	3.35	1.12
Tall oatgrass	0.66	0.00	0.00	0.66	0.22	0.75	0.00	0.00	0.75	0.25
Mountain brome	3.55	2.79	1.30	7.64	2.54	2.32	0.10	0.00	2.42	0.81
Smooth brome	1.59	1.46	0.00	3.05	1.02	1.37	0.65	0.00	2.02	0.67
Red fescue	0.86	0.00	0.00	0.86	0.29	1.39	0.00	0.00	1.39	0.46
Total	9.11	7.51	3.24	19.86	6.62	8.22	1.69	0.02	9.93	3.31
Average	1.82	1.50	0.65	3.97	1.32	1.64	0.34	0.01	1.99	0.66
Fertilizers										
Check - None	1.70	1.42	0.72	3.84	1.28	1.64	0.35	0.02	2.01	0.67
Nitrogen	1.63	1.48	0.56	3.67	1.22	1.80	0.19	0.00	1.99	0.66
Phosphorus	1.95	1.66	0.54	4.15	1.38	1.80	0.38	0.00	2.18	0.73
N + P	1.80	1.46	0.64	3.90	1.30	1.52	0.48	0.00	2.00	0.67
Complete	2.03	1.49	0.78	4.30	1.44	1.46	0.29	0.00	1.75	0.58
Total	9.11	7.51	3.24	19.86	6.62	8.22	1.69	0.02	9.93	3.31
Average	1.82	1.50	0.65	3.97	1.32	1.64	0.34	0.01	1.99	0.66

Table 19.—Number of plants per foot of row by species and by fertility treatment on the Buffer Plot at Philadelphia Flat and Summit Enclosure for three consecutive fall plantings (1957 - 1959)

	Philadelphia Flat				Summit Enclosure			
Species	Seedling year	Second growing season	Third growing season	Total	Seedling year	Second growing season	Third growing season	Total
Intermediate wheatgrass	1.13	1.48	0.00	2.61	1.47	0.47	0.18	2.12
Agropyron spp.	2.07	1.18	-	3.25	1.66	1.29	-	2.95
Stiffhair wheatgrass	1.80	1.07	0.00	2.87	1.35	0.09	0.08	1.52
Meadow foxtail	0.46	0.02	0.00	0.48	0.56	0.01	0.00	0.57
Orchardgrass	1.19	0.99	0.00	2.18	0.98	0.02	0.00	1.00
Chewings fescue	-	-	0.00	0.00	-	-	0.00	0.00
Total	6.65	4.74	0.00	11.39	6.02	1.88	0.26	8.16
Fertilizers								
Check - None	1.51	0.90	0.00	2.41	1.43	0.38	0.12	1.93
Nitrogen	1.10	1.11	0.00	2.21	1.25	0.30	0.02	1.57
Phosphorus	1.33	0.95	0.00	2.28	1.24	0.54	0.00	1.78
N + P	1.43	0.81	0.00	2.24	1.07	0.29	0.08	1.44
Complete	1.28	0.97	0.00	2.25	1.03	0.37	0.04	1.44
Total	6.65	4.74	0.00	11.39	6.02	1.88	0.26	8.16

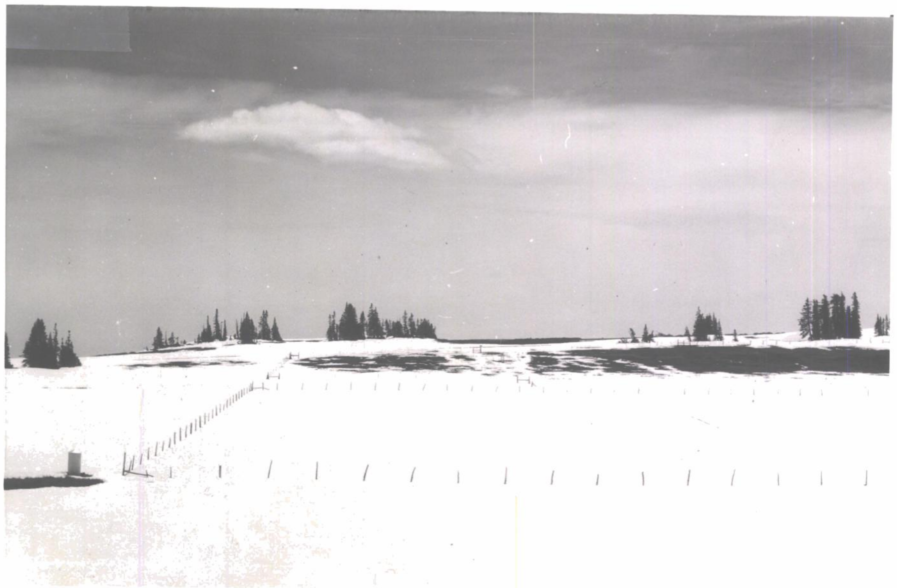


Figure 20.--Snow melted from the Summit area on May 24 and May 25. Snow melted from this area earlier in the spring than at Philadelphia Flat due to exposure and wind action (60-24).

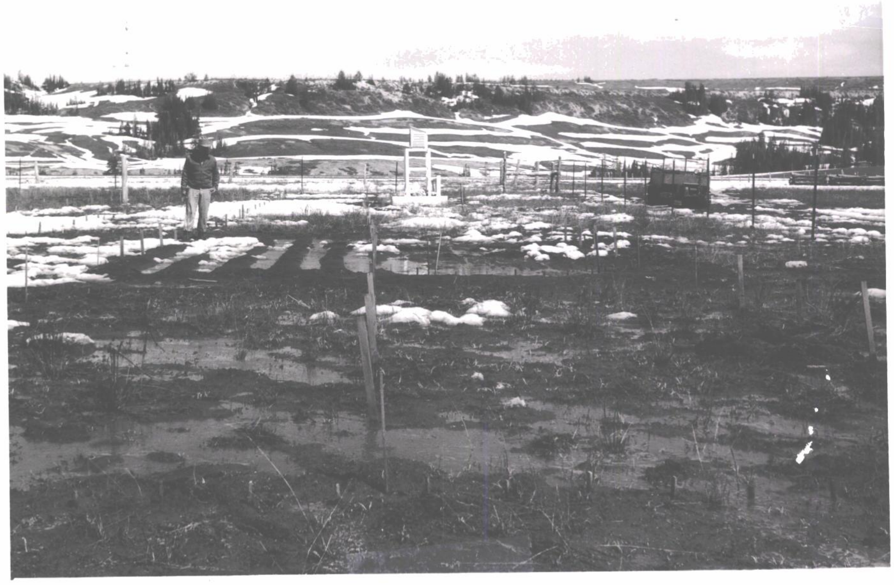


Figure 21.--Rapid snow melting on June 1, 1960 exposed most of the plot area. By June 3 the soil surface was drying with a slight crust (60-79).

The treatment that has been consistently best at Summit Enclosure is sawdust mulch and the spring drilling has been next best. Plant numbers were low on other treatments at the Summit Enclosure.

IV-B. Stand establishment and free-water in the snow and on the soil surface

Fall plantings at high elevations in central Utah have usually been successful but on some local areas and in other parts of the Intermountain Region fall plantings have failed repeatedly. The reasons for these failures have been obscure since species used, seed quality, depth of planting, competition, available soil moisture, and similar factors have not appeared to be the cause of these failures. An examination of some of these plantings has shown that good stands are frequently growing on rocky ridges and south or west facing slopes when poor stands are growing on the deep fertile soils in the swales and valleys. High water marks and other signs observed in the spring of 1956 indicated that water reached a depth in excess of 3 and 5 inches, respectively, on two separate test areas. Snow survey notes substantiated these findings and indicated that melted snow water may accumulate under the snow under certain conditions.

To test this theory, free-water traps were made by placing a small can, bottom side up, over the top of an open 1/2 quart beverage can, as a loose lid. Small air holes were made on the side of this lid, allowing air to escape when water entered. These cans were fastened together with wire so that bottom of the inverted can was at least 1/2 inch above the top of the beverage can. The larger diameter of the top can gave a minimum of 1/4 inch of space between the sides of the top can and the beverage can. These traps could only be filled by flowing water. Cans were then buried in the soil so that the lip of the beverage can was 1, 2, or 3 inches above the soil surface.

Traps set out in the fall of 1956, 1957, 1958, and 1959 and checked in the following spring showed that free-water under snow existed on some heavy textured soil that drain rapidly when the soil is snow-free. A water table in the snow, on top of the soil, is formed when the water produced on an area from rapid snowmelt plus supplemental drainage into the area exceeds the percolation rate of water into the soil plus overland drainage from this area. Overland drainage from these areas is reduced or delayed by the snowpack which not only reduces the rate of flow itself but also holds soil, litter, and sticks which also reduce the movement of water through the snow.

Row plantings were usually made adjacent to free-water traps so that correlation of seedling stands on these areas could be made with depth of free-water. Furrows 20 to 100 feet long and 4 inches deep were made with a hand cultivator. Seeds of smooth brome were planted at a depth of 3/4-inch in the bottom of each furrow with a Planet Jr. Seeding rate with the Planet Jr. was set for 10 pounds per acre when rows were spaced 1 foot apart.

Plantings were made in the fall of 1956, 1957, 1958, and 1959 on the same areas. Seedling stands in the spring of 1957, 1958, and 1959 were included in the respective reports. Seedling stands in the spring of 1960 and supplemental information are shown below.

1. Philadelphia Flat - Elevation 10,000 feet
    a. Uniform area. Cans at 1 inch level filled. Fair stands of smooth brome (2.1 plants per foot).
    b. Sack and row area. Cans at 1, 2, and 4-inch levels were filled with water. Fair stand of smooth brome (1.9 plants per foot).
    c. From level terrace up a slope. Cans at 1 inch level filled on level terrace and on slope of 6 percent.

2. Summit Enclosure near uniform study area - Elevation 10,200 feet. Free-water traps at 1 inch level filled with water and considerable flooding observed during rapid spring snowmelt. Good seedling stand of smooth brome (5.0 plants per foot of row).

3. Alpine Summit.- Elevation 10,200 feet. Snow cover on this west facing area was shallow in comparison to Philadelphia Flat and other level areas. Soil was frozen during most of the winter. Seeds germinated in the spring. Good seedling stands on June 10, 1960 with 6.0 seedlings per foot of row. Frost action and heaving killed some seedlings. Water traps were not filled.

4. Rock Monument on Skyline Drive - Elevation 10,300 feet. Free-water traps at 1- and 2-inch levels were filled with water. Two seedlings of smooth brome per foot of row.

5. Bear Creek - Elevation 9,900 feet. Established on upper portion of a livestock exclosure. Good seedling stands with 16 plants of smooth brome per foot of row. Water traps were not filled on this area and had been heaved out of the soil.

6. Manti Seeding - Elevation 9,800 feet.

   a. Level terrace - eight seedlings per foot of row. Traps at 1, 2, and 4 inch levels filled.

   b. North slope. Five seedlings per foot of row. No water traps filled.

   c. West slope. Four seedlings per foot of row. No water traps filled.

A cooperative study between the Watershed Management Research Division of the Intermountain Forest and Range Experiment Station, Forest Service, and the Ephraim Project was activated to develop equipment that would record the occurrence, frequency, and duration of free-water in the soil and at selected points in the snow during spring snowmelt. Since the "free-water traps" in use only determined the occurrence of free-water but did not show duration or frequency suitable equipment was needed. This information is needed because flooding may have an adverse effect on germinating seeds, seedlings and even established plants. Snow hydrologists are interested because the presence of free-water is vital to the study of snowmelt.

Two replications of snow and soil units were made. Units were laboratory tested and installed on Philadelphia Flat where water tables in the snow were known to have occurred in the spring of 1957. This equipment was placed in operation about April 1 and continuous operation was maintained during the active snowmelt period in the spring of 1958, 1959, and 1960. In each replication a soil unit was placed 3/4-inch (2 cm.) below the soil surface and 4 units were placed in the snow at 1/2, 1, 2, and 4 inches above the soil surface. Thus, a total of 10 units were wired to the electronic unit which in turn was connected to a 10-pen Esterline-Angus recorder (figures 22 and 23).

This study has shown that soil was saturated at intervals during the late spring period prior to rapid snowmelt with peak water depths occurring in the late afternoon. Continuous flooding for over 36 hours on this area has occurred although conditions especially favoring deep flooding have not occurred since the spring of 1957. Conditions favoring maximum flooding are large volumes of high density snow and warm air temperatures during both day and night, coupled with warm winds and high radiation from the sun during the latter part of the snowmelt period.

Figures 22 and 23.--Soil and snow units recorded the occurrence and duration of free-water in the soil in the spring of 1960. Ten electronic units were connected to a 10-pen Esterline-Angus recorder (60-68 and 60-81).

Degree of flooding and depth of flooding during rapid snowmelt in the spring of 1960 was greater than expected. Although snow depth was quite shallow and temperatures were lower than in previous years flooding was extensive on a large portion of the land at high elevations above Ephraim. The primary reason appeared to be due to the presence of frozen soil on many large areas which greatly reduced percolation of water into the soil and thus increased runoff. In the spring of 1957, 1958, and 1959 the soil was frozen on exposed ridges and where snow was shallow but on most areas the soil under the deep snow was thawed and moist below the soil surface during late winter and spring.

Free-water traps and row plantings were placed at selected areas on October 22, 1960 to obtain additional information on free-water depths under the snow and during rapid spring snowmelt and the fate of seeds subjected to existing conditions. Traps and three or more rows of smooth brome were placed at the following locations in the fall of 1958.

1. Philadelphia Flat
    a. Harsh site - Uniform study area
    b. Near seed germination and emergency study
    c. From level bottom up a slope for a distance of 300 feet with traps at 50 foot intervals with all cans placed 1 inch above the soil surface.
2. Uniform study area at Summit Enclosure
3. Monument on Skyline Drive, south of John August Lake
4. Head of Ephraim Canyon, above the Alpine Cabin.

5. Bear Creek plot area

6. Manti Canyon seeding

    a. Level terrace

    b. North slope

    c. West slope

IV-C. Pocket gophers on rangelands.

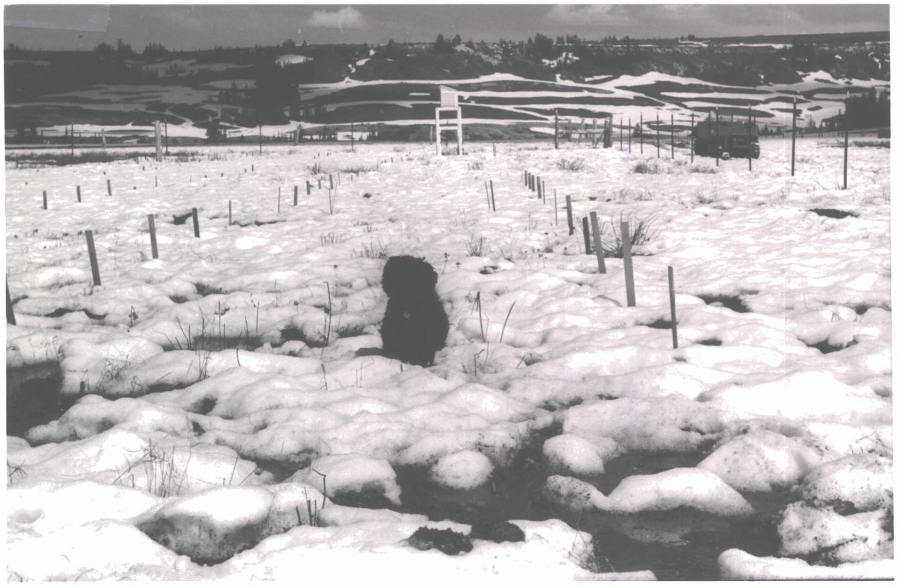
Pocket gopher activities have been followed and studied in conjunction with other work because of the damage these animals have done to seeded stands, revegetation studies and especially to the seed germination studies conducted under snow. Workings by these animals have been numerous on most harsh sites at high elevations in Utah where the vegetation has been depleted. Gophers directly damaged planted and native grasses and forbs by eating or destroying leaves, crowns, roots, or indirectly damaged these plants by covering seeds, seedlings, or established plants with winter soil casts or summer soil mounds.

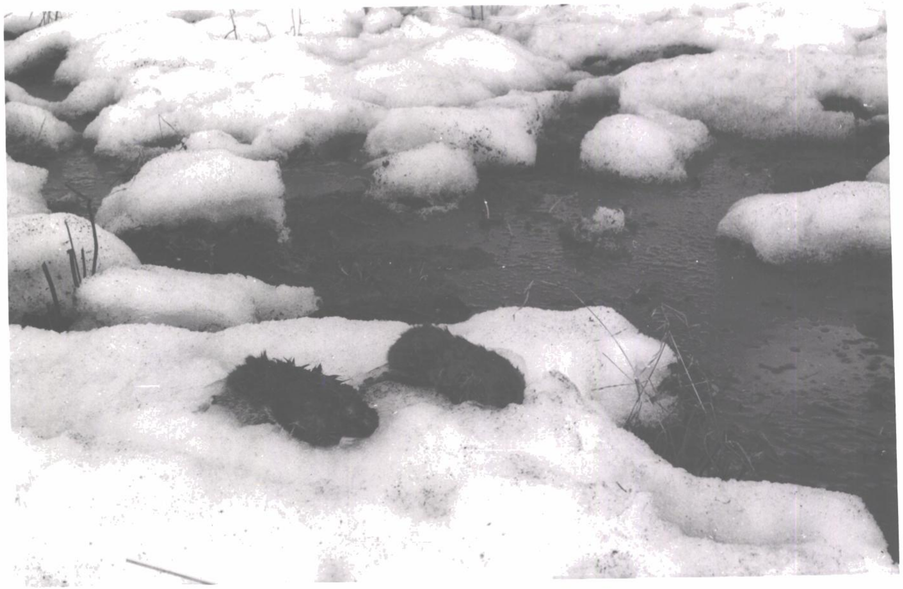
High gopher populations have been observed on many depleted high elevation sites. Pocket gophers were trapped in the fall of 1957, 1958, 1959, and 1960 on and near several revegetation study areas at approximately 10,000 feet in central Utah. Records of total animals caught have been kept on a 4-acre area located on Philadelphia Flat for the years 1958, 1959, and 1960. In 1958 a total of 63 animals or 15.8 gophers per acre were trapped. In 1959, 102 animals (46 adults and 56 young gophers) or 25.5 gophers per acre were trapped. In 1960 only 42 gophers (17 adults and 25 young) or 10.5 gophers per acre were caught. The number shown for 1960 includes three gophers that were killed in the early spring just as the snow was leaving the area.

A sharp decline in pocket gopher numbers at high elevation occurred from the fall of 1959 to the summer of 1960. Only moderate winter activity in the snow was observed and a moderate number of winter cores were visible just as the snow was leaving in the spring of 1960, indicating a decline in gopher activity from the high population in the spring of 1959. This lack of winter activity may have been due to the heavy freezing of soil during the fall and winter of 1960 before deep permanent snow covered this area. Some soil thawing occurred during March, April, and May under the snow but the soil was still partly frozen on many areas when the rapid snowmelt occurred in late May of 1960. This frozen soil resulted in higher flooding and more runoff than would have occurred with the existing snow if the water could have percolated into the soil.

This buildup of water resulted in a flooding on many of the below ground burrows and the gophers were drowned or forced above ground. Where snow remained, gophers were found buried in the snow just above the free-water but other gophers were forced into the open where they were exposed to predatory birds and animals. Gophers taking refuge in the shallow snow were also easy prey for predatory animals as demonstrated by my dog. This dog was observed killing three gophers on the Philadelphia Flat plot study area and several on the surrounding area. Two of the gophers killed on the study area are shown in figures 24 and 25.

Gopher activity in the snow above the soil surface increased markedly after the February-March period of 1957, 1958, and 1959 and continued until snowmelt in the spring. Much of the surface soil was frozen at high elevations in 1960 and accelerated gopher activity in the snow was not observed until March. The increased activity in the



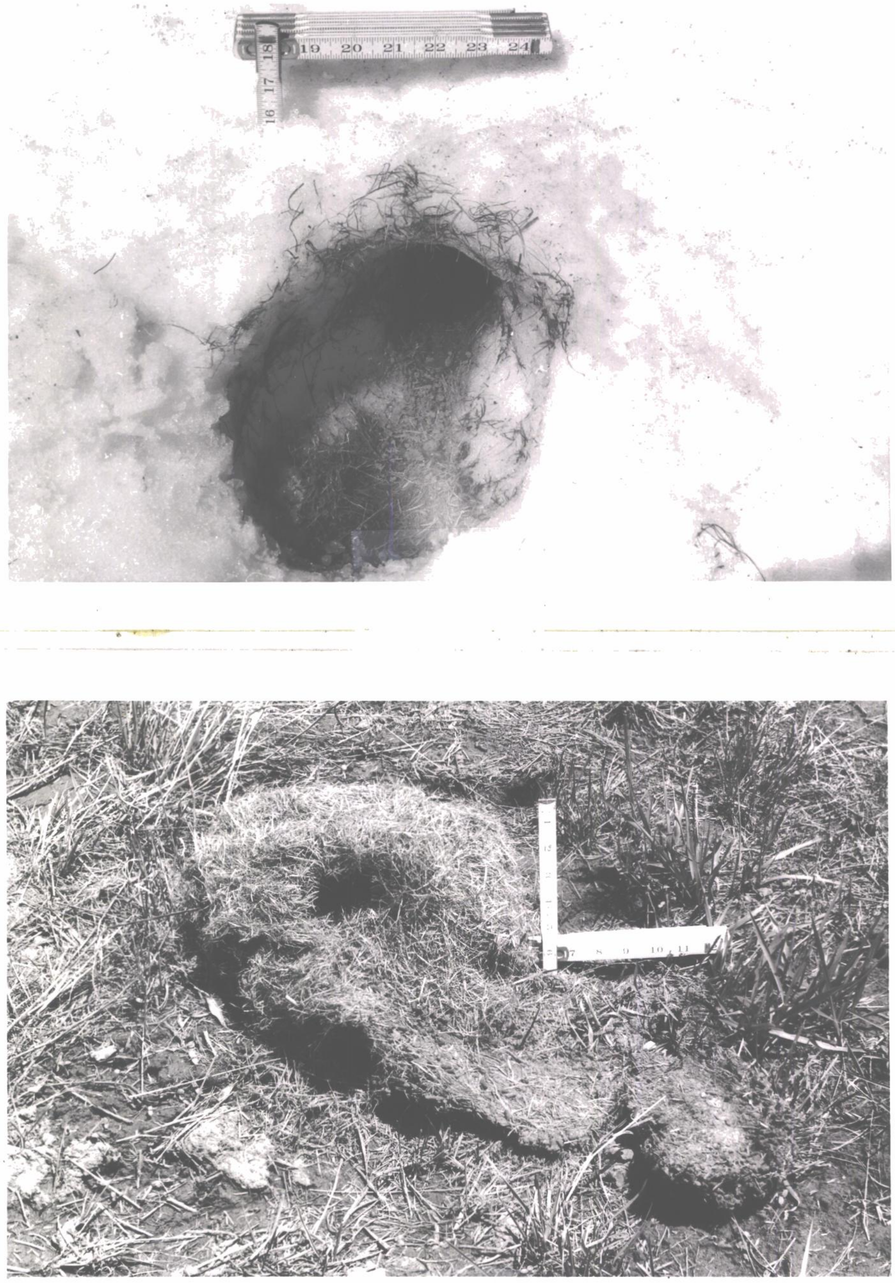


Figures 24 and 25.--The pocket gophers shown in the foreground of these photos were flooded out of their underground burrows on the Philadelphia Flat plot area in the spring of 1960. Although the gophers remained buried in the snow just above the free-water level they were easily located and killed by the dog shown in the upper photo (60-62 and 60-72).

February-March period appears to be related to thawing of the soil when it has been frozen, an increase in temperatures of the surface soil and snow near the soil surface, depletion of stored food reserves, additional food supply provided by an elongation of grasses and forbs and a need for storage space for soil and waste material.

A large number of nests have been observed. Most of these have been at least 6 inches above the soil surface (figure 26) but in the spring of 1959 and 1960 several nests were found just above the soil surface (figure 27) or in shallow excavations below the soil surface. Nests found in the snow have usually been lined with dried grass or shredded bark. A number of soil filled nests have also been found. These nests were built with grass lined bottoms and sides similar to that shown in figure 26 and then the nest and the tunnels leading to the nest have been filled with soil and other waste material. One system of soil casts observed in the spring of 1960 contained three soil filled nests.

Most of the burrows and soil casts observed in the snow were within 3 inches of the soil surface but one cast, 27 inches above the soil surface, was found in the spring of 1958. Gopher damage was rather severe on the study areas on Philadelphia Flat in the spring of 1957, 1958, and 1959 but little damage was observed in the spring of 1960. Where casts were placed in the snow or near the soil surface the casts often followed depressions in the soil such as furrows. On furrowed plots where gophers were active, from 11 to 37 percent of the drill rows in the bottoms of the furrows were covered with soil



Figures 26 and 27.--Most of the gopher nests found in the snow have been at least 6 inches above the soil surface. The bottom of the nest in the upper photo was 7 inches above the soil surface. The nest in the lower photo was originally about 2 inches above the soil surface (60-74 and 60-140).

casts. These casts were usually 1-1/2 to 2-1/2 inches in diameter; thus seeds and seedlings were often covered with 2 to 3 inches of soil when casts were placed in the bottom of the furrows directly over the seed. Number of seedlings were decreased from 35 to 90 percent where soil casts covered the seed row. Some damage to established plants has been observed when casts covered the crowns but mortality of these plants has not been high.

Pocket gophers apparently eat a wide variety of plants. Food caches observed in the spruce-fir zone frequently contained roots of dandelion, tubers of starwort, corms of springbeauty, and bulbs of troutlily, although some caches have been predominantly or exclusively one species. Most of the food caches found have been in the snow at least 6 inches above the soil surface. In the spring of 1960 a cache was found in a burrow below the soil surface (figure 28).

Established grasses, forbs, and shrubs have been damaged or killed when the root system or crowns have been disturbed by burrowing gophers. Damage has occurred both in summer and winter and at relatively low and high elevations. Stands of established crested wheatgrass, Indian ricegrass, and other grasses were severely damaged on a shadscale type near Gunnison, Utah. Primary damage was effected by burrowing beneath the plants and either eating or cutting the root systems. Damage to many other plants including shadscale and fourwing saltbush also occurred on this site. Shrubs were killed by severing the roots as shown in figures 1 and 2. Apparently the missing root was used as food since all roots between the main stem and the lower root stub had been removed from the soil.

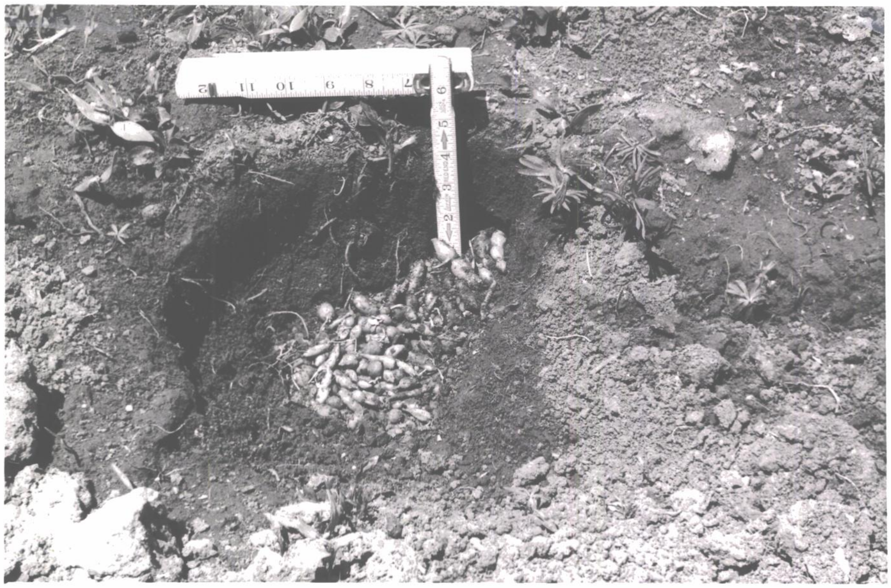


Figure 28.--This food cache, located approximately 1 week after the snow melted in the spring of 1960 was located in a burrow below the soil surface (60-141).

Field observations have shown that pocket gophers show a preference for some plants for food. In plant nurseries located at various elevations in Ephraim Canyon, gopher workings will often be concentrated within areas where preferred plants are growing. At a mountain brush site a concentration of mounds and soil casts were found within an area planted to alfalfa while very few mounds were located in the surrounding grass plots (figure 29). In the grass nurseries the gophers showed preference for orchardgrass, tall oatgrass, timothy, bulbous barley, and quackgrass. Observations made in 1958, 1959, and 1960 indicated that considerable utilization of grasses and forbs took place above the soil surface during the winter or spring when the area was covered with snow. Gophers showed a marked preference for orchardgrass. Winter cores on many orchardgrass and other grass plots frequently consisted of dead stems and leaves and waste material that had been removed from the area around the living plants to enable the gophers to reach the green leaves and living crowns (figure 30). Observations made in the fall prior to snowfall, in the spring after snowmelt, and in the summer have shown that the orchardgrass plots utilized under the snow by gophers are also utilized by rabbits during the growing season. Photos similar to figure 31 which show the winter gopher casts consisting of dead leaves and stems also frequently show numerous rabbit droppings.

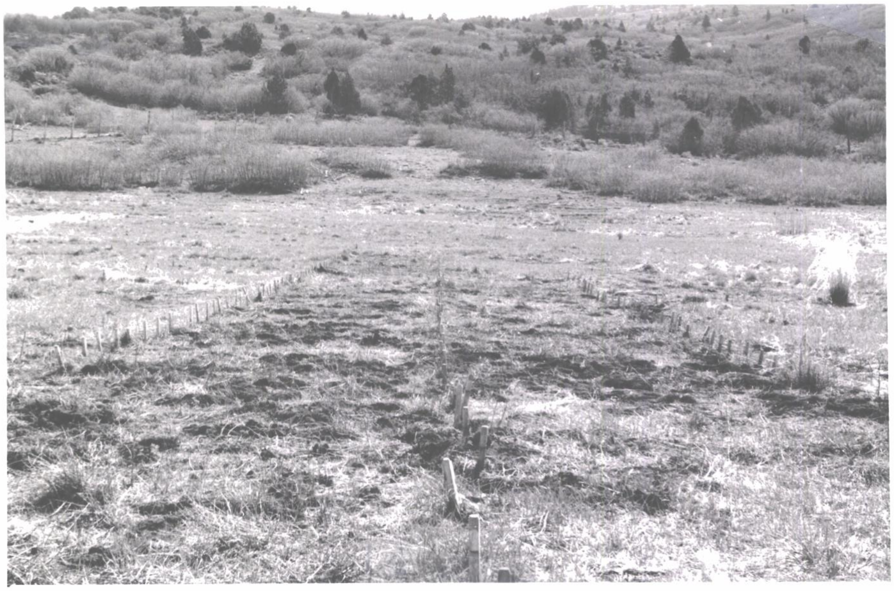


Figure 29.--Gophers show a preference for some plants for food. Note the concentration of gopher mounds within the alfalfa rows in the center of the photo while very few mounds can be seen in the surrounding grass plots (60-8).

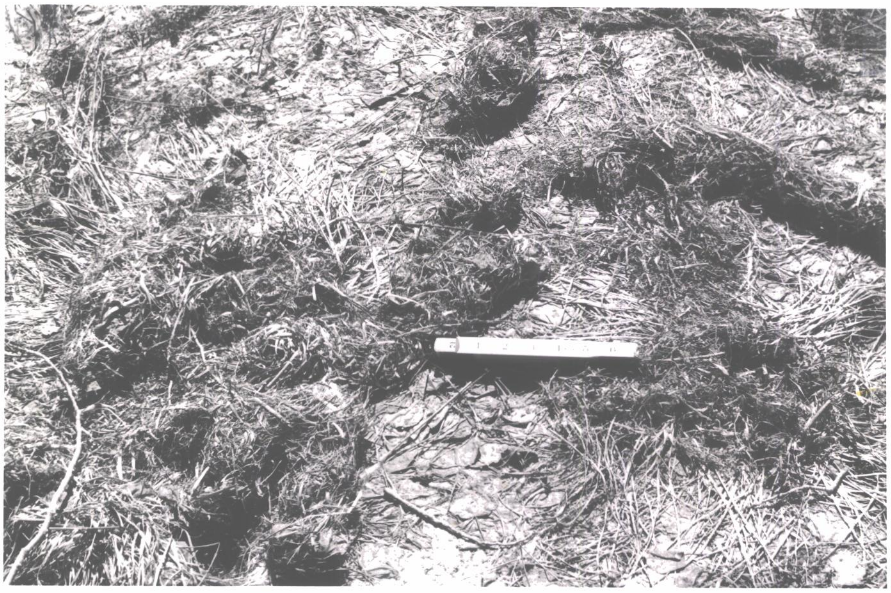


Figure 30.--Winter gopher casts on orchardgrass and other grass plots frequently consisted of dead leaves and stems and other waste material that had been removed to enable the gophers to reach the growing leaves and living crowns (60-59).

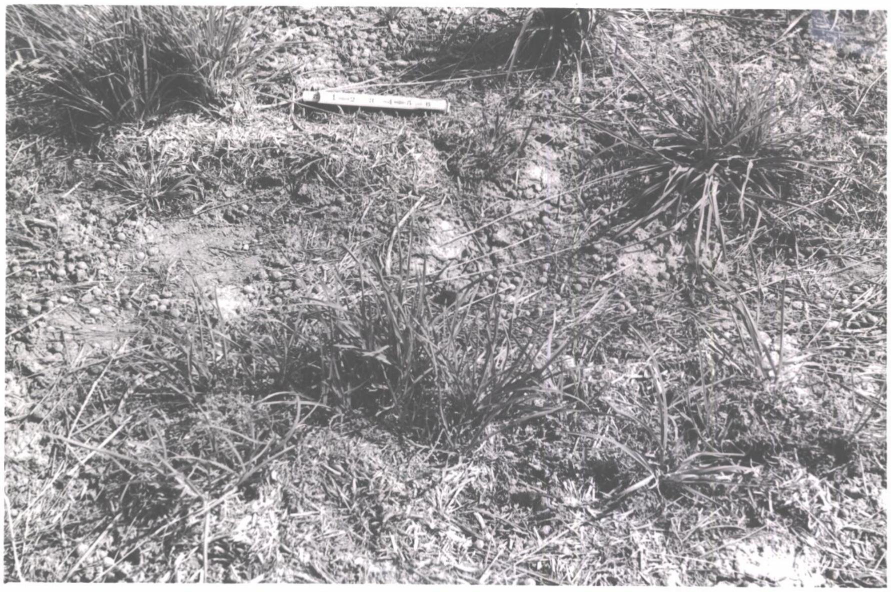


Figure 31.--Concentrations of rabbit pellets and winter gopher casts were frequently found on the same plots where preferred grasses such as orchardgrass and forbs such as alfalfa were growing (60-17).

IV-D. Decomposition of organic matter during the winter at high elevations

Decomposition of organic matter under a deep snow cover has been marked during the winters of 1956-1957, 1957-1958, 1958-1959, and 1959-1960. New cotton broadcloth bags buried under snow and soil in the fall of 1956 and 1957 were largely disintegrated by the time snow had melted in the spring of both years. In August 1958, herbage production within an enclosure on a high elevation depleted site averaged 1,200 pounds dry weight per acre. By snowmelt on June 3, 1959 only 110 pounds of total litter per acre could be collected on this same area.

Decomposition appears to be primarily due to the action of fungi and perhaps bacteria. Numerous earthworms have also been observed in the aspen-fir type, above the soil surface of unfrozen soil under a deep snow cover, from March until snow melts in the spring. Other worms and a few insects have also been observed above the soil surface on thawed soil below a snow cover. No attempt has been made to study the existing soil flora and fauna.

Decomposition of organic matter may indirectly influence seed germination. The energy released with the breakdown of large quantities of organicmatter undoubtedly contributes to the warming or thawing of the soil surface that usually occurs in the spring. The release of carbon dioxide and other grasses could influence seed germination. Also, a litter modifies the soil temperature, soil moisture content, rate of snowmelt, and other environmental conditions that influence seed germination and stand establishment. One observation is that litter and dry plant material will frequently cause a build-up of snow because it acts as a windbreak and also the soil under litter is usually at a lower temperature during the early fall, allowing snow accumulation. However, after prolonged cold winter temperatures the soil under the litter is usually warmer than bare soil not exposed to the sun. Rate of snowmelt is usually faster where dead stems and litter are abundant due to the absorption of radiation by the litter, the higher temperatures of the soil under the litter, and the heat released by decomposition of the organic material (figure 32).

During the summer of 1959 plants of smooth brome, slender wheatgrass, tall bluebell, and mountain lupine were harvested in the hay stage and dried in the sun and stored until October 5. These species were selected to obtain one grass and one forb with coarse stems, and one grass and one forb with relatively fine stems. Percent leaves and stems were determined for each species.

All species were air dried in the laboratory and divided into samples containing 25 or 40 grams air-dry weight. Only the seed stalks and pods were removed from the vegetative material used. Six units of each species were placed in fine mesh nylon bags and the bag openings were sewn. Three of the nylon bags contained 25 grams air-dry weight and 3 bags contained 40 grams air-dry weight. Six units of each species with a net air-dry weight of 40 grams were also placed in aluminum foil bags. Representative samples in aluminum foil were placed in an oven at 80°F. for 24 hours to obtain oven-dry weights for all

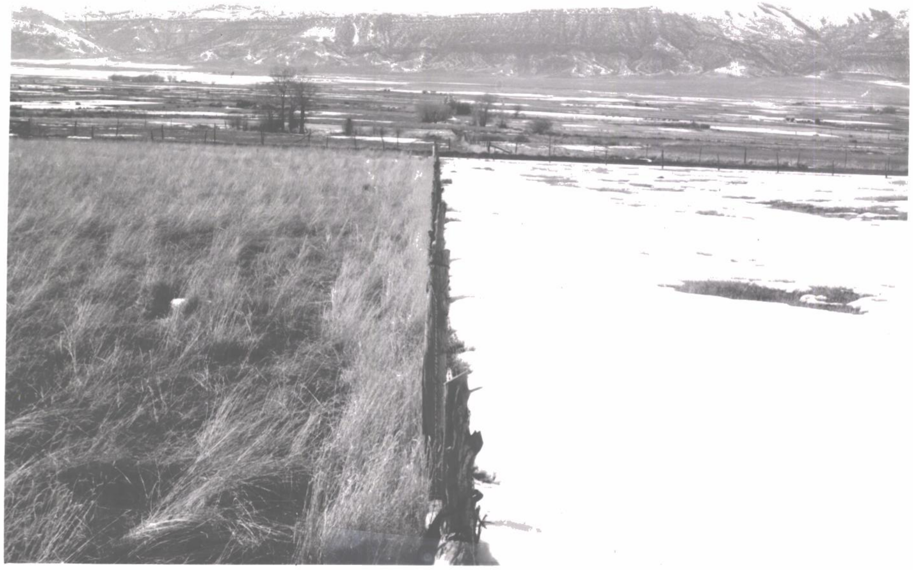


Figure 32.—Snow remains on a heavily grazed crested wheatgrass pasture for a longer period in the winter months than where litter and dry plant stems remain (58-3).

samples. Thus, samples used for decomposition measurement were not subjected to high temperatures which could produce changes in the organic material or destroy flora or fauna on this material.

Samples in aluminum foil were placed under a tin shed in late September 1959 and remained there until June 10, 1960. Openings in the foil bags were arranged to allow free passage of air but protected the samples from falling moisture and dust. The three samples that were selected at random were used to determine the ovendry weight in the fall of 1959 and the remaining three were to determine net weight loss in the air and also to determine ovendry weights for all species in the summer of 1960.

Nylon bags were placed on the bare soil surface within the enclosure on Philadelphia Flat on October 2, 1959. Two bags containing plant material of each species were placed under frames that allowed free-air circulation but prevented the snowpack from pressing directly down on the bags. Bags were covered with shallow snow from October 2 to December 12 and with 18-inches to 66-inches of snow from December 12 to May 27. The remaining 18-inches of snow melted during the period May 28 to June 2.

All bags were removed from the area on June 9, 1 week after the snow had melted (figure 33). Soil and litter were removed from the outside of the bags by gentle brushing and bags were taken to the laboratory. No attempt was made to remove soil that had filtered into the bags. All bags from the field and all bags from the tin shed were

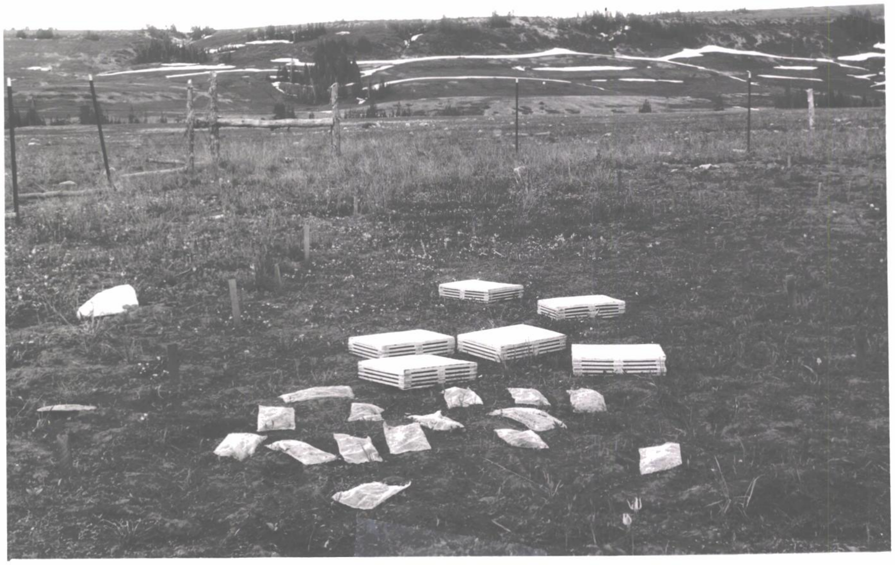


Figure 33.--Plant material in fine mesh nylon bags was removed from Philadelphia Flat 1 week after the winter snow had melted (60-112).

uniformly dried in the laboratory for 4 weeks. Air-dry weights were taken on all samples at this time and ovendry weights were then determined on three of the samples that were in aluminum foil. All air-dry weights were then changed to ovendry weights based on these determinations. The change in ovendry weights on the samples stored in the shed ranged from a - 0.81 percent to a + 0.94 percent.

As shown in table 20, the plant material in nylon bags lost from 25.53 to 52.18 percent of the original weight during the winter period that the sacks were on the soil surface. Actual weight loss is estimated to be at least 10 percent greater than shown due to infiltration of soil into these bags. Since equipment is not available for precision assay, quantitative measurements have not been made.

It is interesting to note that the decomposition of relatively coarse stems and leaves of slender wheatgrass and lupine was less than decomposition of the finer leaves and stems of smooth brome and bluebell, although lupine had 61 percent leaves while bluebell had only 46 percent leaves. Percent decomposition of plant material under the wooden frames was less for all samples than for the material placed on the soil surface in direct contact with the snow. This is probably due to the crushing action of the snowpack, the closer contact with the soil surface, and the infiltration of water from the snowpack through the bags.

Table 20 .--Decomposition of plant material of four species on the soil surface during the winter months

Species	Sample Air-dry weight (Grams)	Average Composition Leaves (Percent)	Average Composition Stems (Percent)	Net Oven-dry wt. 1959 (Grams)	Net Oven-dry wt. 1960 1/ (Grams)	Change in wt. Decomposition (Grams)	Change in wt. Decomposition (Percent)
Slender wheatgrass	25	27	73	23.26	16.62	6.64	28.55
	25	27	73	23.26	16.09	7.17	30.83
	25 2/	27	73	23.26	17.06	6.20	26.66
	40	27	73	37.21	26.52	10.69	28.73
	40	27	73	37.21	26.43	10.78	28.97
	40 2/	27	73	37.21	27.71	9.50	25.53
Smooth brome	25	55	45	23.26	14.40	8.86	38.09
	25	55	45	23.26	13.62	9.64	41.44
	25 2/	55	45	23.26	16.46	6.80	29.23
	40	55	45	37.21	26.67	10.54	28.33
	40	55	45	37.21	24.42	12.79	34.37
	40 2/	55	45	37.21	27.37	9.84	26.44
Lupine	25	61	39	23.01	13.96	9.05	39.33
	25	61	39	23.01	13.90	9.11	39.59
	25 2/	61	39	23.01	15.71	7.30	31.73
	40	61	39	36.81	21.90	14.91	40.51
	40	61	39	36.81	21.18	15.63	42.46
	40 2/	61	39	36.81	23.56	13.25	36.00
Bluebell	25	46	54	23.21	12.63	10.58	45.58
	25	46	54	23.21	11.69	11.52	49.63
	25 2/	46	54	23.21	15.47	7.74	33.35
	40	46	54	37.14	21.08	16.06	43.24
	40	46	54	37.14	17.76	19.38	52.18
	40 2/	46	54	37.14	21.20	15.94	42.92

1/ Samples contain soil which infiltrated into the bags but quantitative measurements have not been made at this time.

2/ Samples under wooden frames.

IV-E. Revegetation trials on range watersheds at high elevations

Most of the intermediate and high elevation ranges are important to the Intermountain Region, both as a watershed and for forage production. Many of these ranges are in a depleted condition. Stock exclosures established on representative areas 20 to 50 years ago have shown little or no improvement through natural revegetation.

Generally speaking good grass stands have been obtained by selected species, planted by recommended methods at intermediate and high elevations (figure 34). Reduction of competing vegetation has been necessary for rapid plant establishment. Drilling with a standard drill, broadcasting and harrowing, or broadcasting on freshly plowed ground has usually given good results, but planting in furrows (deep or semi-deep) has usually given the best results.

At high elevations smooth brome has been the best single species (figure 35). Good stands have been produced with many other species including tall oatgrass, slender wheatgrass, mountain brome, timothy, orchardgrass, intermediate wheatgrass, Kentucky bluegrass, and quackgrass. The rhizomatous grasses have usually been superior to the bunchgrasses because they spread vegetatively and are long-lived. Seedlings of the rhizomatous grasses Kentucky bluegrass, quackgrass, and smooth brome made in 1917 by Dr. A. W. Sampson are still present and largely controlling soil erosion although heavy grazing has been the practice. Short-lived plants such as slender wheatgrass and mountain brome have produced good stands but these stands usually deteriorate and perish. Unless these short-lived plants are replaced through natural revegetation the soil is left bare,(table 21).

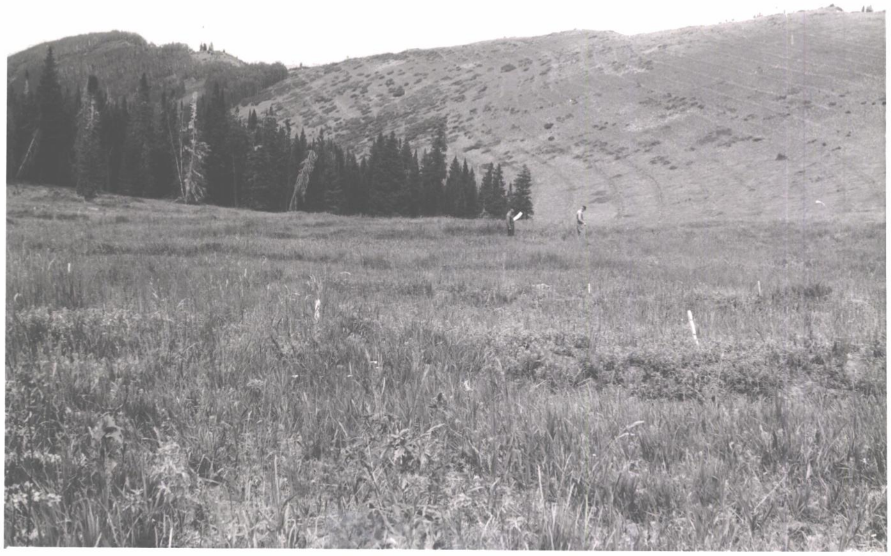


Figure 34.--Good stands of grasses were obtained from a fall of 1950 planting on the range watershed above Mt. Pleasant, Utah (60-184).

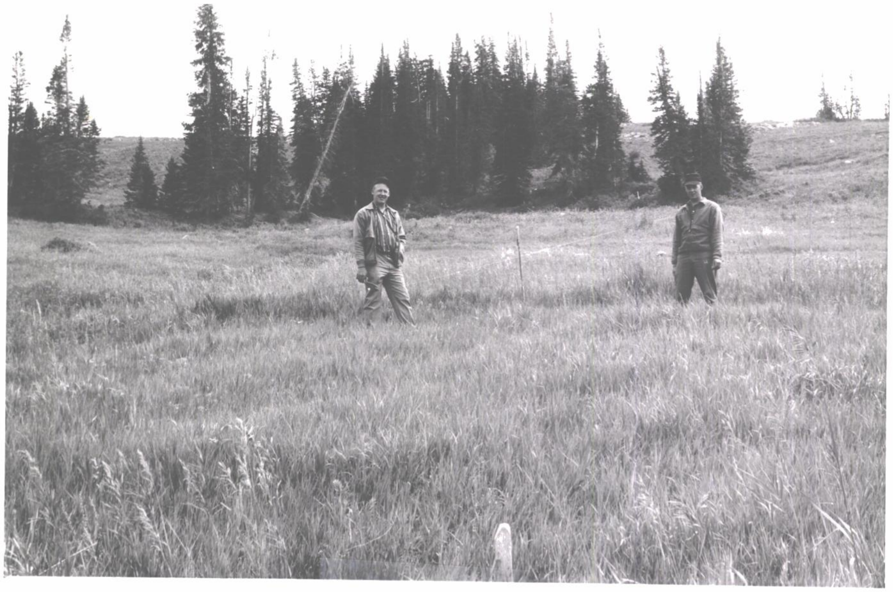


Figure 35.--At high elevations smooth brome has been the best single species. A southern strain (Lincoln) can be seen on the left of the photo and a northern strain is on the right side of the photo (60-193).

Table 21 .--Average relative plot ratings in 1953 and 1960 and dry weight yields per acre in 1960 for 13 species or strains and a mixture of these species planted on a depleted range and watershed in the fall of 1950

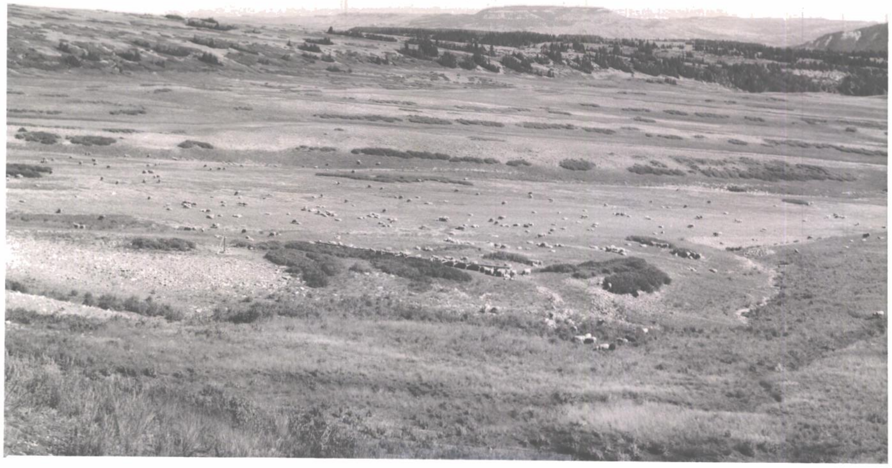
Planted Species	Relative 1/ Rating		Plants Per Sq. Ft.	Yield 1960		
	1953	1960	1960	Planted Species	Other Species	Total
				- - -Pounds per Acre - - -		
Intermediate wheatgrass	9.1	8.1	Sod	822	472	1294
Quackgrass	9.9	5.2	Sod	309	916	1225
Slender wheatgrass	8.9	4.9	0.6	235	869	1104
Tall oatgrass	8.9	3.1	0.4	259	678	937
Tall oatgrass	8.5	7.2	0.8	880	218	1098
Mountain brome	9.8	7.4	2.5	389	331	720
Meadow brome	8.0	8.1	Sod	935	142	1077
Smooth brome	9.2	9.9	Sod	1903	36	1939
Smooth brome	9.4	9.8	Sod	1925	61	1986
Subalpine brome	8.0	8.5	1.7	1055	188	1243
Orchardgrass	8.2	2.9	0.2	265	740	1005
Tall fescue	5.8	0	0	0	1038	1038
Reed canarygrass	4.3	4.6	Sod	253	836	1089
Mixture	9.0	9.3	Sod	1107	162	1269
Total	117.0	89.0	-	10,337	6,687	17,024.
Average	8.3	6.3	-	738.4	477.6	1216.0

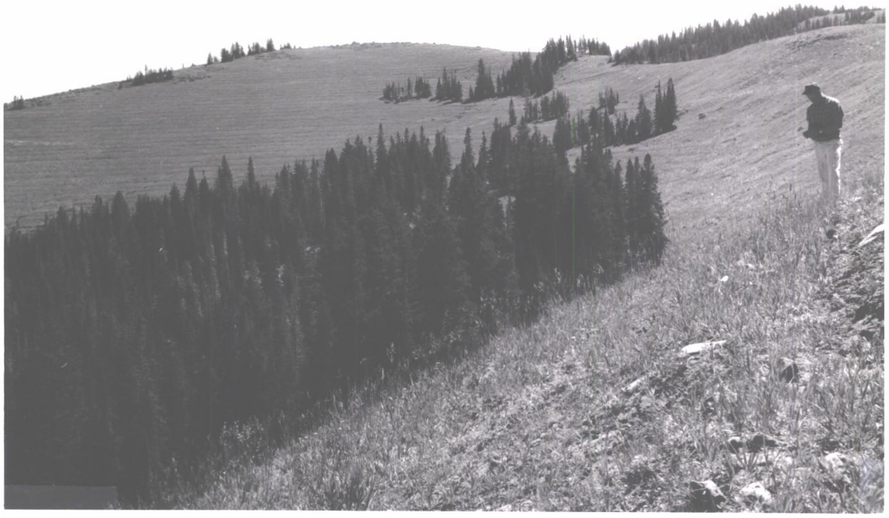
1/ Relative ratings are based on summation of ratings for plant numbers and distribution: 1-2 very poor; 3-4 poor; 5-6 medium; 7-8 good; 9-10 very good.

Much of the topsoil on heavy grazed ranges at high elevations has been lost by erosion (figures 36 and 37). The low fertility and reduced moisture holding capacity of the soil in the remaining subsoil may be a factor in plant establishment, production of forage, and erosion control. On the subalpine plots at Bear Creek good seedling stands were obtained but plant establishment was slow. Some stands obtained have not provided the soil protection required to arrest or retard soil erosion (figure 38). Where the plant cover protected the soil from active erosion relatively rapid soil build-up occurred by soil deposition from surrounding areas and the accumulation of organic matter (figure 39).

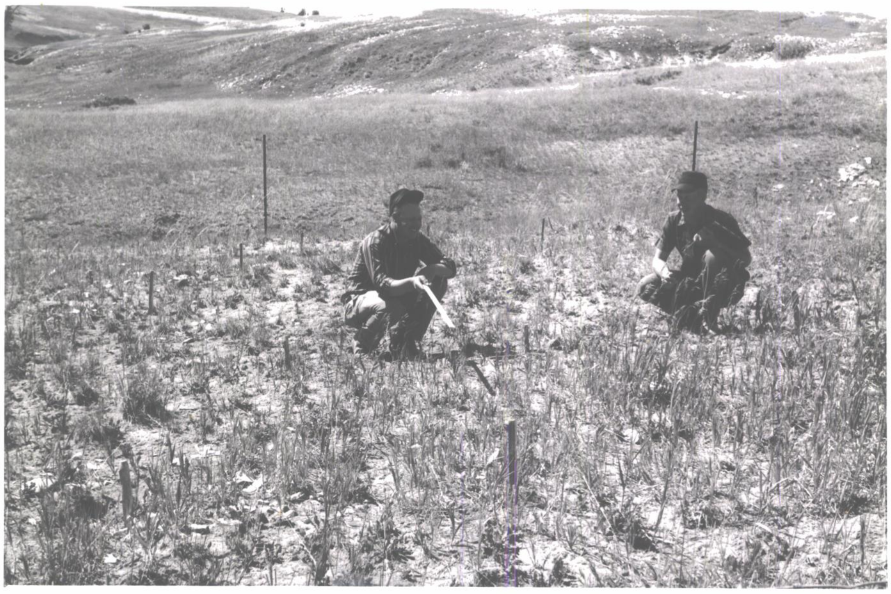
Soil and snow temperatures at or near the soil surface under a snow cover of one or more feet are usually around 30 to 34°F. Seed development and other physiological changes at these temperatures may determine the seedling stands produced. Freezing and thawing of the soil due to diurnal fluctuations in temperature may produce frost damage and heaving (figures 40 and 41). Other factors which may influence production of seedling stands are competition for moisture, shade, moisture holding capacity of the soil, soil structure, microorganisms in the soil, insects, rodents, and climatic conditions.

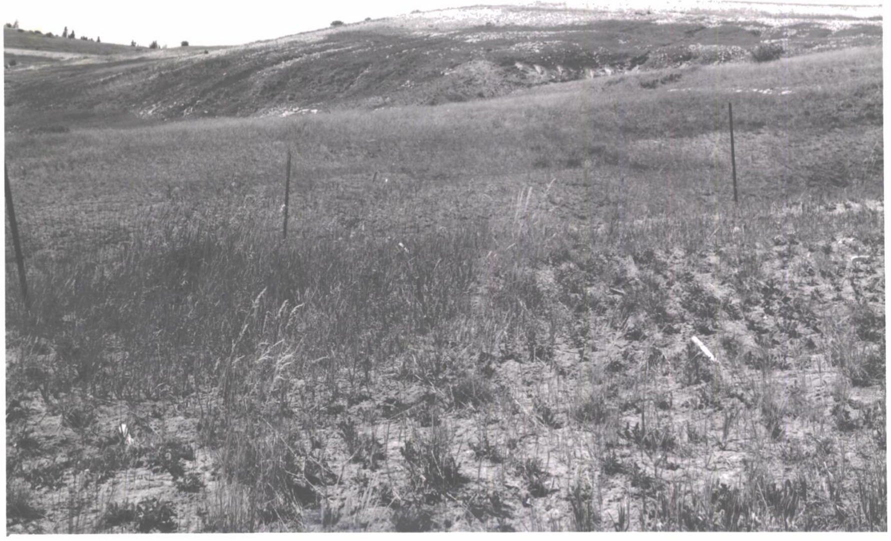
Studies have shown that selected species will do well on some dry, badly eroded steep slopes once they become established. Limited plant establishment has been obtained from direct seeding on these sites, but establishment is usually slow and uncertain. Rhizome





Figures 36 and 37.--Much of the topsoil on the heavy grazed ranges at high elevations has been lost. Loss of this relatively shallow soil reduces moisture holding capacity of the remaining soil mantle and may reduce fertility (60-222 and 60-228).





Figures 38 and 39.--Good seedling stands were obtained from planting in the spring of 1949 and the fall of 1950 on this severely eroded area. In the upper photo smooth brome, slender wheatgrass, and mountain brome have persisted but it has not yet reached the density required to stabilize the soil (60-212). In the lower photo one patch of smooth brome has stabilized the soil and deposition of soil and organic matter has increased the fertility and moisture holding capacity of the soil (60-212 and 60-213).

Figures 40 and 41.--Freezing and thawing of the soil may produce frost damage and heaving. The close-up in the lower photo shows the loose soil mulch produced by heaving (60-106 and 60-105).

plantings have proven to be a dependable method for obtaining stands on small critical areas. Transplanting can be done in the spring, summer, or fall when the soil moisture is adequate for establishment. Spring and summer plantings have been superior to late fall planting on areas where severe frost heaving has occurred in the late fall and early spring. While vegetative propagation will have limited application it may be necessary to restore the vegetative cover on many critical areas where seed plantings have been unsuccessful.